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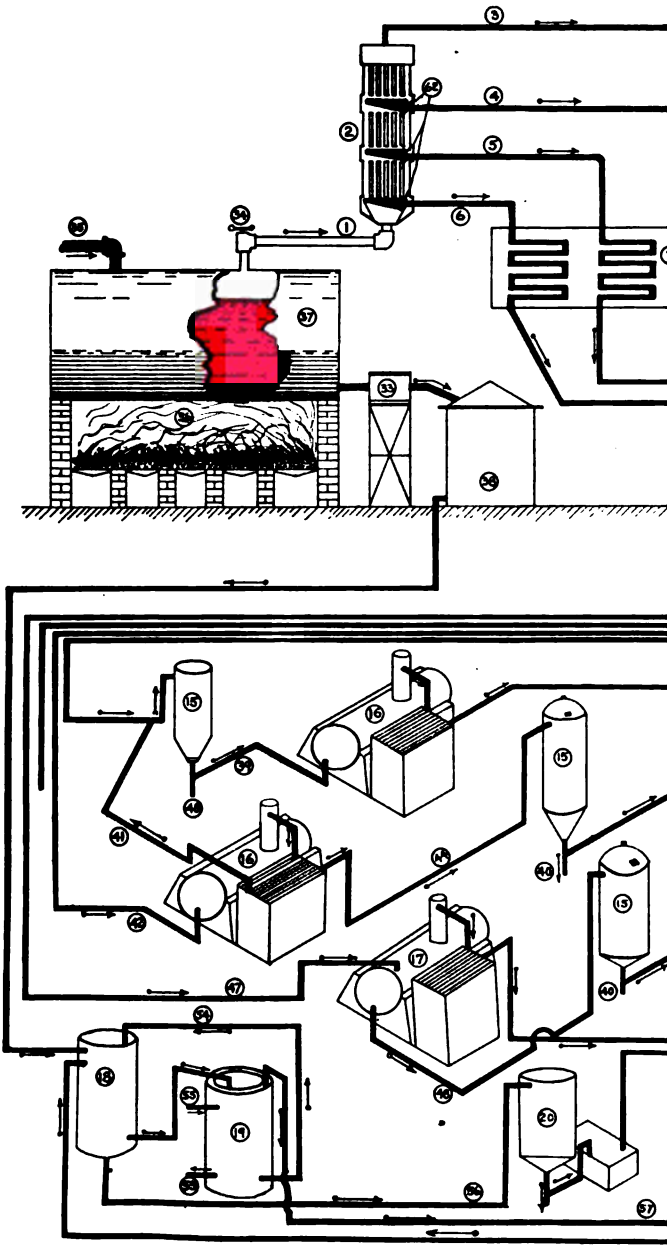
CONTENTS

"The habit of analysis, the ability to get under the surface of things and at the vital essentials, gives a man a tremendous advantage"



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or Cylinder Stocks.

THE HANDBOOK OF
INDUSTRIAL OIL ENGINEERING

A REFERENCE BOOK OF DATA, RELATING TO LUBRICATION AND INDUSTRIAL OILS, INCLUDING TABLES, GENERAL OIL INFORMATION, ENGINEERING AND INDUSTRIAL REQUIREMENTS, FOR THE USE OF OIL ENGINEERS, LUBRICATING ENGINEERS, OIL SALESMEN, OIL EQUIPMENT MANUFACTURERS, MECHANICAL ENGINEERS, MACHINERY DESIGNERS, MILL AND POWER PLANT SUPERINTENDENTS, AND OTHERS INTERESTED IN THE EFFICIENT UTILIZATION OF OIL PRODUCTS AND EQUIPMENT, AND THE CONSERVATION OF POWER. INCLUDES THE LUBRICATING ENGINEER'S HANDBOOK REVISED.

BY

JOHN ROME BATTLE, B.Sc. IN M.E.; M.E.

ASSOCIATE-MEMBER AMERICAN SOCIETY OF MECHANICAL ENGINEERS
MEMBER ENGINEERS' CLUB OF PHILADELPHIA
CONSULTING ENGINEER

LUBRICATION AND INDUSTRIAL OIL SECTION
(COMPLETE)

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

PRINTED BY J. B. LIPPINCOTT COMPANY
AT THE WASHINGTON SQUARE PRESS
PHILADELPHIA, U. S. A.

THE AUTHOR
AFFECTIONATELY DEDICATES
THIS BOOK TO
HIS MOTHER AND FATHER

PREFACE

HANDBOOK OF INDUSTRIAL OIL ENGINEERING AND THE PRACTICE OF LUBRICATION (INCLUDING THE REVISED LUBRICATING ENGINEER'S HANDBOOK)

The keynote of all business of today is efficiency and service.

The world faces an era of great manufacturing activity and keen competition.

Economical and increased production offers a solution of the present conditions. There must, therefore, be a clear survey of all those factors which have a direct bearing upon the rate and cost of manufacturing production. Of these factors, there are none more vital than the economical and efficient operation of mechanical equipment and efficient industrial processes.

Petroleum and other oil products are closely involved in the majority of manufacturing operations and processes, and it is, therefore, important that the utilization of these products in the industries be in accordance with the most efficient practice.

The more severe lubricating requirements of modern machinery; the increasing use of oil fuel for steam boilers and industrial furnaces; and the development of those processes requiring oil products, either as a part of the process, or to enter into the manufactured product, have made it necessary, that the oil refiner and manufacturer render to the industries intelligent service and advice, to insure correct selection and efficient use of their products.

With the increasing consumption of oils, there has been developed much valuable and effective equipment for storing, applying, reclaiming, and measuring oils, designed to meet modern industrial and domestic requirements, and it is advisable that a knowledge of the construction and value of this equipment be more general.

At all times, in the development of the world's natural resources, there has been no single factor which has been more helpful than the engineering profession, and it is, therefore, logical that a specialized branch of engineering, which has for its purpose the economical utilization of one of our most important natural resources—**Oil**—should be recognized.

Unfortunately, in the early stages of the development of any new branch of engineering, a period must be passed through during which the available information and standards of practice are indefinite. Industrial Oil Engineering has passed through such a period, but today emerges, clearly defined as to the scope of its field and rapidly standardizing the principles of its practice.

In the present Industrial Oil Engineering Handbook, much of the data contained in the Lubricating Engineer's Handbook has been revised and used, and considerable new data on this important subject has been added.

The Lubrication and Industrial Oil Section of the Industrial Oil Engineer's Handbook covers the properties and utilization of petroleum products other than for fuel purposes,* and also the properties and uses of many of the most common fatty oils have been touched upon. Such subjects as the Heat Treatment of Steel (involving the use of oil products), Core Oils, Oils and Allied Products Used in the Textile Fields, etc., have been briefly covered. A section on the elements of mathematics and other useful data has been added.

All of these subjects are essentially involved in the general industrial utilization of oil and its products, which comprises the specialized field of the Industrial Oil Engineer.

The aim of the author has been to outline the principles of the various subjects rather than to attempt a treatise, and it is hoped that the reader will judge the value of this handbook from that standpoint.

The author is under continued obligations to many manufacturers and others, who have kindly given permission to use various data, and have offered helpful criticism.

JOHN ROME BATTLE.

Philadelphia, Pa.,
June, 1920.

*ANNOUNCEMENT

The Author has in preparation a manuscript covering an additional section of the Industrial Oil Engineer's Handbook, also complete in itself, on the subject of liquid fuel. The present plans are to include in the Liquid Fuel Section data pertaining to the combustion of oil fuel, together with descriptions and principles of typical oil-burning equipment, and the results of actual practice. It is also planned to include information on fuels for internal-combustion engines.

PREFACE (FIRST EDITION)

LUBRICATING ENGINEER'S HANDBOOK

CONSIDER, that not a spindle can turn without overheating and wear, nor the largest locomotive in the world move a heavy train, unless there is a lubricant provided to reduce the ever-present friction between the bearing surfaces, and the importance of the almost limitless field of "Lubricating Engineering" may be appreciated.

Of all the supplies used in the operation of power plants and industrial mills, lubricants and their practical application are the least understood.

Designers of machinery are interested in the subject of theoretical lubrication and its effect upon the design of machinery bearings.

Operating engineers are interested in the efficient and smooth running of the machines under their charge.

Owners and general managers are interested in lessening the cost of production. This may be accomplished by reducing the friction load of their plants, with the consequent reduction in power costs.

Purchasing agents are interested in the buying of lubricants suitable for use in their plants, at the lowest prices consistent with the quality and physical requirements demanded of these lubricants.

Lubricating oil salesmen of modern times are required to have a general knowledge of the working conditions met with in the various industries, a knowledge of the fundamentals of mechanical and electrical engineering, and a general knowledge of the manufacture and properties of petroleum and other oils and greases.

These are days of efficiency and keen business competition. The oil salesman who is in a position to assist his trade with practical and helpful information bearing upon the lubricating engineering of their equipment will obtain a far greater share of the business in his field than will result from his efforts if he overlooks this important asset.

Manufacturers of lubricants are interested in the marketing of standard brands of oils and greases, especially designed to meet the lubricating requirements of the trade. They are therefore interested in obtaining a concise description of the mechanical and physical conditions affecting the lubrication of the machinery of the various industries.

These conditions were so obvious to me when, as a mechanical engineer, I became associated with the oil business, that I began to collect data and keep a note-book. This data and such descriptions and tables as I have found to be of value to the trade have been included in this handbook, with the earnest desire that they may be found to be unbiased in their recommendations and of practical value in everyday work.

I desire to take this opportunity to thank the manufacturers and others who have kindly assisted me in the securing of much valuable information.

JOHN ROME BATTLE.

Philadelphia, Pa.,
March, 1916.

THE HANDBOOK OF INDUSTRIAL OIL ENGINEERING AND PRACTICE OF LUBRICATION

SECTION I

MATHEMATICS AND USEFUL DATA

FRACTIONS.—The value of a fraction is the "quotient" of the "numerator" divided by the "denominator."

Example:

$$3/4 = 4)\overline{300} \atop .75 \quad \text{or} \quad \frac{75}{100}\text{ths.}$$

To analyze a fraction, viz: 4 is the "denominator" and shows that the "integer" is divided into four parts; it is the "divisor"; 3 is the "numerator" and shows that three parts are taken; it is the "dividend," or "integer divider."

ADDITION OF FRACTIONS.—*Rule:* Reduce to "least common denominator," add the numerators and place sum over least common denominator.

Example:

3/4 + 1/8 + 2/7 + 5/12 (least common denominator is 168)

therefore: $\frac{126}{168} + \frac{21}{168} + \frac{48}{168} + \frac{70}{168} = \frac{265}{168}$

$$\frac{265}{}$$

168)265(1 97/168 answer.
168
97

NOTE. Reduce improper fractions to whole or mixed numbers.

SUBTRACTION OF FRACTIONS.—*Rule:* Reduce the fractions to a common denominator; subtract the numerators and place the difference over the common denominator.

Example:

(1/2 — 2/9) common denominator = 18

1/2 = 9/18

2/9 = 4/18

9/18 — 4/18 = 5/18 answer

NOTE. Reduce mixed numbers to improper fractions.

MULTIPLICATION OF FRACTIONS.—*To multiply a fraction by a whole number. Rule:* Multiplying by a fraction consists in *multiplying* by the numerator and *dividing* by the denominator.

Example: If one gallon of oil costs 3/4 of a dollar, how much will 5 gallons cost?

$$3/4 \times 5 = \frac{15}{4} \qquad 4\,)\,15\,(\,\underline{3\ 3/4}\ \text{answer}$$
$$\begin{array}{r} 12 \\ \hline 3 \end{array}$$

To multiply a whole number by a fraction. Rule: Multiplying a whole number by a fraction consists in multiplying by the numerator and dividing by the denominator of the multiplier. *Example:* At \$75 per barrel, what will 3/5 of a barrel cost?

$75 \times 3 = 225$
$225 \div 5 =$ \$45, which is the cost of 3/5 of a barrel.

To multiply a fraction by a fraction. Rule: Multiply the numerators and the denominators.

Example:

$$3/4 \times 4/9 = 12/36 = 1/3 \text{ answer}$$

NOTE. Reduce whole and mixed numbers to improper fractions. Cancel all factors common to both numerator and denominator.

DIVISION OF FRACTIONS.—*To divide a fraction by a whole number. Rule:* Divide the numerator or multiply the denominator of the fraction by the whole number.

Example:

$$9/10 \div 3 = 3/10 \text{ answer}$$
or
$$9/10 \div 3 = 9/30 = 3/10 \text{ answer}$$

To divide a whole number by a fraction. Rule: Multiply the whole number by the denominator and divide by the numerator of the divisor.

Example:

$12 \div 3/4$
$12 \times 4 = 48 \qquad 48 \div 3 = 16$ answer

To divide a fraction by a fraction. Rule: Invert the divisor and proceed as in multiplication of fractions. Reduce whole numbers and mixed numbers to improper fractions.

Example:

$$7/8 \div 3/4 = 7/8 \times 4/3 = \frac{28}{24} \qquad 24\,)\,28\,(\,\underline{1\ 4/24}\ \text{answer.}$$
$$\begin{array}{r} 24 \\ \hline 4 \end{array}$$

$$1\ 4/24 = 1\ 1/6 \text{ answer}$$

DECIMALS

.5 = 5 tenths expressed in one figure.
.05 = 5 hundredths expressed in two figures.
.005 = 5 thousandths expressed in three figures.

Prefixing a cipher to a decimal *decreases* its value the same as dividing by 10.

Thus .03 is 1/10 of .3.

Affixing a cipher to a decimal does not alter its value, thus:

$$6/10 \text{ or } .6 \text{ is the same as } \frac{60}{100} \text{ or } .60$$

Decimals *increase from right to left and decrease from left to right* in ten-fold parts.

The denominator of a decimal, though never expressed, is always the unit (1), with as many ciphers annexed as there are figures in the decimal.

Write the decimal the same as a whole number, placing ciphers where necessary to give each significant figure its true local value.

Place the decimal point before the first figure.

Numerate from the decimal point, to determine the denominator.

Numerate towards the decimal point, to determine the numerator.

Read the decimal as a whole number, giving it the name or denominator of the right hand figure.

TO REDUCE DECIMALS TO A COMMON DENOMINATOR.—*Rule:* Give each number the same number of decimal places by annexing ciphers.

Example:

Reduce .5 and .375 and 46.13 to least common denominator:

$$\begin{array}{r} .500 \\ .375 \\ 46.130 \end{array}$$

TO REDUCE DECIMALS TO COMMON FRACTIONS.—*Rule:* Omit the decimal points and supply the proper denominator. The denominator is (1) with as many ciphers annexed as there are decimal places in the numerator.

Example:

Reduce .125 to a common fraction:

$$\frac{125}{1000} = \frac{25}{200} = \frac{1}{8} \text{ answer}$$

TO REDUCE COMMON FRACTIONS TO DECIMALS.—*Rule:* Annex ciphers to the numerator prefixed by a decimal point and divide by the denominator. Point off as many decimal places in the result as there were numbers of ciphers annexed.

Example:

5/8 to a decimal:

$$\begin{array}{l} 8)5.000(\underline{.625} \text{ answer} \\ \underline{48} \\ 20 \\ \underline{16} \\ 40 \\ \underline{40} \end{array}$$

ADDITION OF DECIMALS.—*Rule:* Write the numbers, so that the decimal points shall stand directly under each other. Add, as in whole numbers, and place the decimal point in the result, directly under the points of the numbers added:

Example:

$$\begin{array}{r} .199 \\ 2.7569 \\ .25 \\ .654 \\ \hline 3.8599 \end{array} \text{ answer.}$$

SUBTRACTION OF DECIMALS.—*Rule:* Write the numbers, so that the decimal points stand directly under each other. Subtract as in whole numbers, and place the decimal point in the result, directly under the points in the given numbers.

Example:

Difference between 714. and .916

$$\begin{array}{r} 714.000 \\ .916 \\ \hline 713.084 \end{array} \text{ answer}$$

MULTIPLICATION OF DECIMALS.—*Rule:* Multiply as in whole numbers, and from the right hand of the product, point off as many figures for decimals as there are decimal places in both factors, taken together.

Example:

Multiply 1.245 by .27

$$\begin{array}{r} 1.245 \\ .27 \\ \hline 8715 \\ 2490 \\ \hline 0.33615 \end{array} \text{ answer}$$

DIVISION OF DECIMALS.—*Rule:* Divide as in whole numbers, and from the right hand of the quotient point off as many places for decimals as there are decimal places in the dividend exceeding those in the divisor.

Example:

What is the quotient of .175 divided by .5?

$$\begin{array}{r} .5\overline{).175} \\ .35 \end{array} \text{ answer}$$

If the number of figures in the quotient is less than the excess of decimal places in the dividend over those in the divisor, the deficiency must be supplied, by prefixing ciphers.

If there be a remainder, after dividing the dividend, annex ciphers and continue the division; the ciphers annexed are decimals of the dividend.

The dividend must contain at least as many decimal places, as the divisor, before commencing the division.

In most business transactions, the division is considered sufficiently exact, when the quotient is carried to four places.

GREATEST COMMON DIVISOR

Rule: Write the numbers in a line with a vertical line at the left, and divide by any factor common to all the numbers.

Divide the quotients in a like manner, and continue the division until a set of quotients is obtained that have no common factor.

Multiply all the divisions together, and the product will be the greatest common divisor.

LEAST COMMON MULTIPLE

Rule: Divide by any prime factor that will divide the greatest number without a remainder, and write the quotients and undivided numbers in a line underneath.

Continue the process until all factors of the given numbers have been transferred to the left of the vertical line, then multiply these together and their product will be the least common multiple.

$$\begin{array}{r|rrrr}
2 & 4 & 6 & 9 & 12 \\ \hline
2 & 2 & 3 & 9 & 6 \\ \hline
3 & 1 & 3 & 9 & 3 \\ \hline
3 & 1 & 1 & 3 & 1 \\ \hline
 & & & 1 &
\end{array}$$

$2 \times 2 \times 3 \times 3 = 36$ least common multiple.

LEAST COMMON DENOMINATOR

Rule: Find least common multiple of given denominators for the least common denominator. Divide this by each of the given denominators, and then multiply each numerator by the corresponding quotient. The products will be the new numerators.

Reduce improper fractions to whole or mixed numbers.

Example:

1/6 3/8 5/12 to L. C. D.

$$\begin{array}{r|rrr}
2 & 6 & 8 & 12 \\ \hline
2 & 3 & 4 & 6 \\ \hline
3 & 3 & 2 & 3 \\ \hline
2 & 1 & 2 & 1 \\ \hline
 & & 1 &
\end{array}$$

$2 \times 2 \times 3 \times 2 = 24$ L. C. D.

1/6 = 4/24
3/8 = 9/24
5/12 = 10/24 answer

PERCENTAGE

TO FIND THE PERCENTAGE OF ANY NUMBER.—*Rule:* Multiply the given number or quantity by the rate per cent., expressed decimally, and point off the product as many places as there were decimals.

TO FIND WHAT PER CENT. ONE NUMBER IS OF ANOTHER.—*Rule:* Divide the per cent. by the base and the quotient will be the rate per cent., expressed decimally.

TO FIND A NUMBER WHEN A CERTAIN PER CENT. OF IT IS GIVEN.—*Rule:* Divide the per cent. by the rate per cent., expressed decimally, and the quotient will be the base of the number required.

BROKERAGE

COMMISSION BROKERAGE.—*Rule:* Multiply the given sum by the rate per cent., expressed decimally, and the result will be the commission brokerage.

TO FIND THE COMMISSION OR BROKERAGE, WHEN IT IS DEDUCTED FROM THE GIVEN SUM AND THE BALANCE INVESTED.—*Rule:* Divide the given sum by one (1), increased by the rate per cent. of commission and the quotient is the sum invested. Subtract the investment from the given amount and the remainder is the commission.

Example: $1260 less 5% commission. What is the sum invested?

$$\$1260 \div 1.05 = \$1200$$
$$1260 - 1200 = \$60.00 \text{ commission.}$$

TO FIND THE ADVANCE OF STOCK AT AN ADVANCE OF DISCOUNT.—*Rule:* Multiply the cost of $1 by the number indicating the par value of the stock.

Example: $3240 of stock cost 8% advance, the brokerage being 1/4%:

$$\$3240.$$
$$\$1 + .08 = \$1.08$$
$$\$1.08 + .0025 = \$1.0825 \text{ for one dollar (\$1.00)}$$
$$\$1.0825 \times 3240 = \$3507.30 \text{ cost of stock}$$

TO FIND OUT HOW MUCH STOCK CAN BE PURCHASED FOR A GIVEN SUM.—*Rule:* Divide the given sum by the cost of $1 of stock and the quotient will be the nominal amount of stock purchased.

TO FIND GAIN OR LOSS PER CENT. WHEN THE COST AND SELLING PRICES ARE GIVEN.—*Rule:* Make the difference between the purchase and the selling price the numerator and the purchase price the denominator. Reduce to decimal and the result will be the per cent.

Example: Bought at 32c and sold at 40c:

$$40 - 32 = 8.$$
$$8/32 = 1/4 = 25\% \text{ answer}$$

INTEREST

TO FIND THE INTEREST ON ANY SUM AT ANY RATE OF INTEREST FOR YEARS AND MONTHS.—*Rule:* Multiply the principal by the rate of interest and the product will be the interest for one year. Multiply this product by the time in years and fractions of a year, and the result will be the required interest.

COMPOUND INTEREST.—*Rule:* Find the amount of given principal at the given rate for one year, and then make it the principal for the second year. Find the amount of this new principal for the third year and so on for the given number of years. Subtract the principal from the last amount and the remainder will be the compound interest.

INTEREST TABLES.—To find the interest on any principal, for any number of days, figuring 30 days to the month and 360 days to the year. If the principal contains cents, point off four places from the right of the result to express the interest in dollars and cents. When the principal does not contain cents, point off only two places.

At 3 per cent., multiply the principal by the number of days and divide by 120
At 4 per cent., multiply by the number of days and divide by 90
At 5 per cent., multiply by the number of days and divide by 72
At 6 per cent., multiply by the number of days and divide by 60
At 7 per cent., multiply by the number of days and divide by 52
At 8 per cent., multiply by the number of days and divide by 45
At 9 per cent., multiply by the number of days and divide by 40
At 10 per cent., multiply by the number of days and divide by 36

NOTE. In figuring 360 days instead of 365 days per year, gives 5/365 or 1/73 too much, but the difference is so small that for ordinary business it is not noticed. When the time is shorter than one month, the cents in the principal may be disregarded, because the interest on the cents for that time will not amount to a cent. When the time is less than 2 months disregard cents in principal if less than 50 cents, and when less than 3 months disregard cents in principal under 33 cents.

RATIO AND PROPORTION

Ratio is the relation with each other of two numbers of the same kind.

Ratio is indicated in two ways: (1st) By placing two points between the numbers compared, thus (:), writing the divisor before the dividend. Thus the ratio of 5 to 7 is written thus; 5:7. (2nd) In the form of a fraction, thus the ratio of 9 to 3 is $9/3 = 3$. The "Terms" are the numbers compared. The "Antecedent" is the first term, the "Consequent" is the second term.

A simple ratio consists of a single couplet, as 3:12.

"**Proportion**" is an equality of "ratios." Thus 6:8 and 12:16 being each equal to 3/4 form a proportion. Proportion is indicated by (::).

In a proportion, the first and fourth terms are called the "extremes" and the second and third terms are called the "means." The product of the "means" equals the product of the "extremes"; thus:

$$6:8::9:12$$
$$6 \times 12 = 72 \text{ and } 9 \times 8 = 72$$

ALLIGATION

This treats of the value of a mixture produced by mixing or compounding two or more ingredients of different values. It is the process of finding the average price of a compound of several simple ingredients whose prices and quantities are known.

Rule: Divide the entire cost or value of the ingredients by the sum of the simples.

Example: A mix is made of 40 gals. of Rape Oil @ 80c per gal.
25 gals. of Paraffin Oil @ 25c per gal.
15 gals. of Castor Oil @ $1.50 per gal.

what is the value per gallon of the product?

$$\begin{array}{rcr} 80 \times 40 & = & \$32.00 \\ 25 \times 25 & = & \$6.25 \\ 150 \times \underline{15} & = & \underline{\$22.50} \\ 80 & & \$60.75 \end{array} \qquad 80\,)\,\underline{\$60.75} \quad 75.93 \text{ or } 75.9\text{c per gal}$$

LOGARITHMS

Definition: If three numbers, which can be designated as (a), (b), (c), have such values that the equation:

$$a = b^c$$

is true, then (c) is called the logarithm of (a) to the base (b). If, then, without changing (b), we give to (a) and (c) all possible values, consistent with the above equation, the values of (c) thus obtained form a system of logarithms to the base (b). We can then define a logarithm as follows:

The logarithm of a number to a given base is the exponent of the power, to which the base must be raised, to produce the number. Thus, if (9) is taken as the base, then:

$$\begin{aligned} &\text{Log. } 81 = 2 &&\text{because } 9^2 = 81 \\ &\text{Log. } 729 = 3 &&\text{because } 9^3 = 729 \\ &\text{Log. } 9 = 1 &&\text{because } 9^1 = 9 \\ &\text{Log. } 1 = 0 &&\text{because } 9^0 = 1 \end{aligned}$$

In every system of logarithms, the logarithm of the base is (1), and the logarithm of (1) is (0). Since any number will serve as a base of a system of logarithms, the number of systems is practically unlimited.

The most common systems of logarithms are:

(a) The common, or Briggs System, with the base (10).

(b) The natural, or Napierian System, with the base

$$(e) = 2.7182818285 \ldots .$$

COMMON LOGARITHMS.—The Briggs System is used for all numerical calculations, while the Napierian is used for purely analytical purposes. As stated, the common or Briggs logarithm of a number is the exponent or index of the number, as a power of (10),

Thus, $1000 = 10^3$,
and the log. of 1000 (logarithm of 1000) = 3.000
Similarly,

$$\begin{aligned} &\text{Log. } 100 = 2, &&\text{because } 10^2 = 100 \\ &\text{Log. } 10 = 1, &&\text{because } 10^1 = 10 \\ &\text{Log. } 0.1 = -1, &&\text{because } 10^{-1} = .1 \\ &\text{Log. } .001 = -3, &&\text{because } 10^{-3} = .001 \end{aligned}$$

CHARACTERISTIC AND MANTISSA.—A logarithm consists usually of two parts; a whole number, called the "characteristic," and a fractional portion, called the "mantissa." The logarithm table gives only the mantissa. The characteristic, which may be positive, negative or zero, must be supplied in every case by the user, and it precedes the decimal point.

The mantissa follows the decimal point and is always positive, except in logarithms of exact powers of (10), when it is zero. The mantissa remains constant for any given combination of significant figures in a number, wherever the decimal point in the number may occur.

The characteristic of the logarithm of a number greater than unity is one less than the number of significant figures preceding the decimal point in the number, while the characteristic of the logarithm of a number less than unity is negative and is numerically one greater than the number of ciphers between the decimal point and the first significant figure. Thus the characteristics of the following are shown:

Characteristic of log.	.9426	= -1
Characteristic of log.	62893.	= 4
Characteristic of log.	.07296	= -2
Characteristic of log.	.00042	= -4
Characteristic of log.	765.94	= 2

TO FIND THE LOGARITHM OF A NUMBER OF THREE SIGNIFICANT FIGURES:—If the number has less than three figures, add ciphers on the right and give three figures. If the number has three figures, enter the table shown on the following pages, in the left-hand column, marked (N), with the first two figures, and with the third figure, in the line running across the extreme top of the table. Go across the table, in the line containing the first two figures, until the column marked by the third figure is reached. The three figures found at this point are the mantissa. The characteristic is then prefixed, as previously explained.

EXAMPLES.—To obtain log. 48.6, find (48) in (N) column, and the column marked (6) at the top. The three figures in this column in a line with (48) in the (N) column are (687). Hence, the mantissa of log. 48.6 is (.687). The characteristic of log. 48.6 is 1.

Hence log.	48.6	= 1.687	
Similarly log.	6.2	= 0.792	
Similarly log.	6480.	= 3.812	
Similarly log.	.0431	= -2.634	(sometimes written as 8.634–10)
Similarly log.	.00006	= -5.778	(sometimes written as 5.778–10)

(NOTE. The characteristic of the logarithm of a number less than unity is formed by subtracting from (9) the number of ciphers between the decimal point and the first significant figure, and writing (–10) after the logarithm).

TABLE OF COMMON
(3 PLACE

N	0	1	2	3	4	5	6	7	8	9
10	000	004	009	013	017	021	025	029	033	037
11	041	045	049	053	057	061	064	068	072	076
12	079	083	086	090	093	097	100	104	107	111
13	114	117	121	124	127	130	134	137	140	143
14	146	149	152	155	158	161	164	167	170	173
15	176	179	182	185	188	190	193	196	199	201
16	204	207	210	212	215	217	220	223	225	228
17	230	233	236	238	241	243	246	248	250	253
18	255	258	260	262	265	267	270	272	274	276
19	279	281	283	286	288	290	292	294	297	299
20	301	303	305	307	310	312	314	316	318	320
21	322	324	326	328	330	332	334	336	338	340
22	342	344	346	348	350	352	354	356	358	360
23	362	364	365	367	369	371	373	375	377	378
24	380	382	384	386	387	389	391	393	394	396
25	398	400	401	403	405	407	408	410	412	413
26	415	417	418	420	422	423	425	427	428	430
27	431	433	435	436	438	439	441	442	444	446
28	447	449	450	452	453	455	456	458	459	461
29	462	464	465	467	468	470	471	473	474	476
30	477	479	480	481	483	484	486	487	489	490
31	491	493	494	496	497	498	500	501	502	504
32	505	507	508	509	511	512	513	515	516	517
33	519	520	521	522	524	525	526	528	529	530
34	531	533	534	535	537	538	539	540	542	543
35	544	545	547	548	549	550	551	553	554	555
36	556	558	559	560	561	562	563	565	566	567
37	568	569	571	572	573	574	575	576	577	579
38	580	581	582	583	584	585	587	588	589	590
39	591	592	593	594	595	597	598	599	600	601
40	602	603	604	605	606	607	609	610	611	612
41	613	614	615	616	617	618	619	620	621	622
42	623	624	625	626	627	628	629	630	631	632
43	633	634	635	636	637	638	639	640	641	642
44	643	644	645	646	647	648	649	650	651	652
45	653	654	655	656	657	658	659	660	661	662
46	663	664	665	666	667	667	668	669	670	671
47	672	673	674	675	676	677	678	679	679	680
48	681	682	683	684	685	686	687	688	688	689
49	690	691	692	693	694	695	695	696	697	698
50	699	700	701	702	702	703	704	705	706	707
51	708	708	709	710	711	712	713	713	714	715
52	716	717	718	719	719	720	721	722	723	723
53	724	725	726	727	728	728	729	730	731	732
54	732	733	734	735	736	736	737	738	739	740

LOGARITHMS OF NUMBERS
TABLE)

N	0	1	2	3	4	5	6	7	8	9
55	740	741	742	743	744	744	745	746	747	747
56	748	749	750	751	751	752	753	754	754	755
57	756	757	757	758	759	760	760	761	762	763
58	763	764	765	766	766	767	768	769	769	770
59	771	772	772	773	774	775	775	776	777	777
60	778	779	780	780	781	782	782	783	784	785
61	785	786	787	787	788	789	790	790	791	792
62	792	793	794	794	795	796	797	797	798	799
63	799	800	801	801	802	803	803	804	805	806
64	806	807	808	808	809	810	810	811	812	812
65	813	814	814	815	816	816	817	818	818	819
66	820	820	821	822	822	823	823	824	825	825
67	826	827	827	828	829	829	830	831	831	832
68	833	833	834	834	835	836	836	837	838	838
69	839	839	840	841	841	842	843	843	844	844
70	845	846	846	847	848	848	849	849	850	851
71	851	852	852	853	854	854	855	856	856	857
72	857	858	859	859	860	860	861	862	862	863
73	863	864	865	865	866	866	867	867	868	869
74	869	870	870	871	872	872	873	873	874	874
75	875	876	876	877	877	878	879	879	880	880
76	881	881	882	883	883	884	884	885	885	886
77	886	887	888	888	889	889	890	890	891	892
78	892	893	893	894	894	895	895	896	897	897
79	898	898	899	899	900	900	901	901	902	903
80	903	904	904	905	905	906	906	907	907	908
81	908	909	910	910	911	911	912	912	913	913
82	914	914	915	915	916	916	917	918	918	919
83	919	920	920	921	921	922	922	923	923	924
84	924	925	925	926	926	927	927	928	928	929
85	929	930	930	931	931	932	932	933	933	934
86	934	935	936	936	937	937	938	938	939	939
87	940	940	941	941	942	942	943	943	943	944
88	944	945	945	946	946	947	947	948	948	949
89	949	950	950	951	951	952	952	953	953	954
90	954	955	955	956	956	957	957	958	958	959
91	959	960	960	960	961	961	962	962	963	963
92	964	964	965	965	966	966	967	967	968	968
93	968	969	969	970	970	971	971	972	972	973
94	973	974	974	975	975	975	976	976	977	977
95	978	978	979	979	980	980	980	981	981	982
96	982	983	983	984	984	985	985	985	986	986
97	987	987	988	988	989	989	989	990	990	991
98	991	992	992	993	993	993	994	994	995	995
99	996	996	997	997	997	998	998	999	999	000

USE OF LOGARITHMS.—*To Multiply Numbers:* Find the logarithm of each number and add them; the sum is the logarithm of the product.

To Divide One Number by Another: Find the logarithm of the numbers, and subtract the logarithm of the divisor from the logarithm of the dividend; the difference is the logarithm of the quotient.

To Raise Any Number to Any Power: Multiply the logarithm of the number by the exponent of the power; the product is the logarithm of the required power of the number.

To Extract the Root of a Number: Divide the logarithm of the number by the index of the root; the quotient is the logarithm of the required root of the number.

LOGARITHMS AND CALCULATIONS.—The three place logarithms shown in the table serve for ordinary rapid calculation. For very exact work, four or five place tables are used.

To solve a problem, first set down the whole problem in a continued form. Cancel all the common terms. Then add the logs. of the numerator and the logs. of the denominator (if both multiplication and division are involved) and find the log. of the answer.

Thus:

$$\frac{\overset{2}{\cancel{14}} \times \overset{11}{\cancel{365}} \times 1.14 \times 62 \times \sqrt[3]{64}}{\cancel{7} \times 791 \times .06 \times \cancel{33}}$$

NOTE. All common terms cancelled out to simplify, first, then;

To solve:

$$\left.\begin{array}{ll} \text{Log. } 2 = .301 \text{ .... } & 0.301 \\ \text{Log. } 11 = 1.041 \text{ .... } & 1.041 \\ \text{Log. } 1.14 = 0.057 \text{ .... } & 0.057 \\ \text{Log. } 62. = 1.792 \text{ .... } & 1.792 \\ \text{Log. } \sqrt[3]{64} = 1/3 \text{ log of } 64 = 1/3\ (1.806) \text{ .... } & .602 \\ \hline \text{Carrying out multiplication of numerator} & \\ \quad \text{by adding logs.} = \text{ .... } & 3.793 \end{array}\right\} \text{Numerator}$$

$$\left.\begin{array}{lr} \text{Log. } 791 & 2.898 \\ \text{Log. } .06 & -2.778 \\ \hline \text{Multiplying denominator by adding logs.} = \text{ .... } & 1.676 \end{array}\right\} \text{Denominator}$$

$$\left.\begin{array}{l} \text{Subtracting log. of divisor from log. of dividend:} \\ \quad 3.793 \\ \quad 1.671 \\ \hline \quad 2.117 = \text{log. of } 131 \\ \quad \therefore 131 \text{ is the answer.} \end{array}\right\} \text{Division of Numerator by Denominator}$$

DISCOUNTS

The following table gives the discounts (final) for various percentages:

Discounts			
10 and 5 off	= 14 1/2%	40 and 10 off	= 46%
12 1/2 and 5 off	= 16 7/8%	40, 10 and 5 off	= 48 7/10%
15 and 5 off	= 19 1/4%	40 and 20 off	= 52%
16 2/3 and 10 off	= 25%	40, 20 and 5 off	= 54 2/5%
20 and 5 off	= 24%	45 and 10 off	= 50 1/2%
20 and 10 off	= 28%	50 and 5 off	= 52 1/2%
20, 10 and 5 off	= 31 3/5%	50 and 10 off	= 55%
25 and 5 off	= 28 3/4%	50, 10 and 5 off	= 57 1/4%
25 and 10 off	= 32 1/2%	50 and 20 off	= 60%
25, 10 and 5 off	= 35 7/8%	50, 20 and 5 off	= 62%
30 and 5 off	= 33 1/2%	55 and 10 off	= 59 1/2%
30 and 10 off	= 37%	60 and 5 off	= 62%
30, 10 and 5 off	= 40 1/7%	60 and 10 off	= 64%
33 1/3 and 5 off	= 36 2/3%	60, 10 and 5 off	= 65 4/5%
33 1/3 and 10 off	= 40%	60 and 20 off	= 68%
33 1/3, 10 and 5 off	= 43%	60, 20 and 5 off	= 69 3/5%
33 1/3 and 25 off	= 50%	60 and 25 off	= 70%
40 and 5 off	= 43%	60, 25 and 5 off	= 71 1/2%
		70 and 10 off	= 73%

Aliquot Parts of a Dollar			
50c	= 1/2	12 1/2c	= 1/8
33 1/3c	= 1/3	10c	= 1/10
25c	= 1/4	8 1/3c	= 1/12
20c	= 1/5	6 1/4c	= 1/16
16 2/3c	= 1/6	5c	= 1/20

EQUATION OF PAYMENTS

Equation of Payments is used to determine the time within which one payment can be made to cancel a number of obligations due at different dates. The method is to multiply each item by the days to maturity from a fixed date and divide the sum of the products by the sum of the items. The answer is the average time in days from the fixed date. Thus: Assume A owes B $500 due in 30 days, $200 due in 60 days and $400 due in 90 days. In how many days may the whole be paid in one sum of $1100?

$$500 \times 30 + 200 \times 60 + 400 \times 90 = 63000; \ \frac{63000}{1100} \approx 57.2 \text{ days answer}$$

MENSURATION

AREAS OF PLANE FIGURES

SQUARE.—*Rule for Area:* The area of a square is equal to the square of the length of one side.

RECTANGLE.—*Rule for Area:* The area of a rectangle is the product of the length of one of the short sides times the length of one of the long sides.

TRIANGLES.—*Rule for Area:* The area of a triangle is equal to the product of the length of the base times one-half of the perpendicular height of the triangle, or the altitude.

TRAPEZOID.—*Rule for Area:* The area of a trapezoid is equal to one-half (1/2) the sum of the lengths of the top and bottom (or parallel sides), multiplied by the perpendicular distance between them.

ANY QUADRILATERAL FIGURE.—*Rule for Area:* The area of any quadrilateral figure may be obtained by dividing the quadrilateral in two triangles and then obtaining their area as above.

GEOMETRY

GENERAL PROPOSITIONS.—(a) For any quadrilateral, the sum of the interior angles equals four right angles.

(b) For a right-angled triangle, the sum of the squares of the two sides is equal to the square of the hypothenuse.

(c) A straight line tangent to a circle meets it only at one point. A radius drawn to that point will be perpendicular to the tangent.

(d) All triangles that have equal sides have equal angles and *vice versa.*

CIRCLES

Notation

d = diameter of the circle.	c = chord of a segment, length of.
r = radius of the circle.	h = height of a segment.
p = periphery or circumference.	s = side of a regular polygon.
a = area of a circle or part thereof.	v = centre angle.
b = length of a circle-arc.	w = polygon angle.

All measures must be expressed in terms of the same unit.

Formulas for the Circle

Periphery or Circumference	*Diameter and Radius*	*Area of the Circle*
$p=\pi d \quad =3.14d.$	$d=\frac{p}{\pi} \quad =\frac{p}{3.14}.$	$a=\frac{\pi d^2}{4}=0.7854d^2.$
$p=2\pi r \quad =6.28r.$	$r=\frac{p}{2\pi} \quad =\frac{p}{6.28}.$	$a=\pi r^2=3.14r^2.$
$p=2\sqrt{\pi a}=3.54\sqrt{a}.$	$d=2\sqrt{\frac{a}{\pi}}=1.128\sqrt{a}.$	$a=\frac{p^2}{4\pi}=\frac{p^2}{12.56}.$
$p=\frac{2a}{r} \quad =\frac{4a}{d}.$	$r=\sqrt{\frac{a}{\pi}}=0.564\sqrt{a}.$	$a=\frac{pr}{2}=\frac{pd}{4}.$

* π=3.141 592 653 589 793 238 462 643 383 279 502 884 197 169 399

NOTE.—(π) is usually taken as 3.1416 and $\left(\frac{\pi}{4}\right)$ as .7854

2π= 6.283 185	$\frac{1}{4}\pi$=0.785 398	$\frac{1}{\pi}$=0.318 310	$\frac{360}{\pi}$=114.5915
3π= 9.424 778	$\frac{1}{3}\pi$=1.047 197	$\frac{2}{\pi}$=0.636 619	π^2 = 9.869 650
4π=12.566 370	$\frac{1}{2}\pi$=1.570 796	$\frac{3}{\pi}$=0.954 929	$\sqrt{\pi}$= 1.772 453
5π=15.707 963	$\frac{1}{8}\pi$=0.392 699	$\frac{4}{\pi}$=1.273 239	$\sqrt{\frac{1}{\pi}}$= 0.564 189
6π=18.849 556	$\frac{1}{6}\pi$=0.523 599	$\frac{6}{\pi}$=1.909 859	$\sqrt{\frac{\pi}{2}}$= 1.253 314
7π=21.991 148	$1/12\pi$=0.261 799	$\frac{8}{\pi}$=2.546 478	$\sqrt{\frac{2}{\pi}}$= 0.797 884
8π=25.132 741	$\frac{2}{3}\pi$=2.094 394	$\frac{12}{\pi}$=3.819 718	
9π=28.274 334	$1/360\pi$=0.008 726		

Log. π=0.497 149 872 69413

AREAS AND CIRCUMFERENCES OF CIRCLES (BY SIXTEENTHS TO 5)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
1/64	.049087	.00019						
1/32	.098175	.00077	1.	3.14159	.78540	3.	9.42478	7.0686
3/64	.147262	.00173	1/16	3.33794	.88664	1/16	9.62113	7.3662
1/16	.196350	.00307	1/8	3.53429	.99402	1/8	9.81748	7.6699
3/32	.294524	.00690	3/16	3.73064	1.1075	3/16	10.0138	7.9798
1/8	.392699	.01227	1/4	3.92699	1.2272	1/4	10.2102	8.2958
5/32	.490874	.01917	5/16	4.12334	1.3530	5/16	10.4065	8.6179
3/16	.589049	.02761	3/8	4.31969	1.4849	3/8	10.6029	8.9462
7/32	.687223	.03758	7/16	4.51604	1.6230	7/16	10.7992	9.2806
1/4	.785398	.04909	1/2	4.71239	1.7671	1/2	10.9956	9.6211
9/32	.883573	.06213	9/16	4.90874	1.9175	9/16	11.1919	9.9678
5/16	.981748	.07670	5/8	5.10509	2.0739	5/8	11.3883	10.321
11/32	1.07992	.09281	11/16	5.30144	2.2365	11/16	11.5846	10.680
3/8	1.17810	.11045	3/4	5.49779	2.4053	3/4	11.7810	11.045
13/32	1.27627	.12962	13/16	5.69414	2.5802	13/16	11.9773	11.416
7/16	1.37445	.15033	7/8	5.89049	2.7612	7/8	12.1737	11.793
15/32	1.47262	.17257	15/16	6.08684	2.9483	15/16	12.3700	12.177
1/2	1.57080	.19635	2.	6.28319	3.1416	4.	12.5664	12.566
17/32	1.66897	.22166	1/16	6.47953	3.3410	1/16	12.7627	12.962
9/16	1.76715	.24850	1/8	6.67588	3.5466	1/8	12.9591	13.364
19/32	1.86532	.27688	3/16	6.87223	3.7583	3/16	13.1554	13.772
5/8	1.96350	.30680	1/4	7.06858	3.9761	1/4	13.3518	14.186
21/32	2.06167	.33824	5/16	7.26493	4.2000	5/16	13.5481	14.607
11/16	2.15984	.37122	3/8	7.46128	4.4301	3/8	13.7445	15.033
23/32	2.25802	.40574	7/16	7.65763	4.6664	7/16	13.9408	15.466
3/4	2.35619	.44179	1/2	7.85398	4.9087	1/2	14.1372	15.904
25/32	2.45437	.47937	9/16	8.05033	5.1572	9/16	14.3335	16.349
13/16	2.55254	.51849	5/8	8.24668	5.4119	5/8	14.5299	16.800
27/32	2.65072	.55914	11/16	8.44303	5.6727	11/16	14.7262	17.257
7/8	2.74889	.60132	3/4	8.63938	5.9396	3/4	14.9226	17.721
29/32	2.84707	.64504	13/16	8.83573	6.2126	13/16	15.1189	18.190
15/16	2.94524	.69029	7/8	9.03208	6.4918	7/8	15.3153	18.665
31/32	3.04342	.73708	15/16	9.22843	6.7771	15/16	15.5116	19.147
1.	3.14159	.78540	3.	9.42478	7.0686	5.	15.7080	19.635

Areas and Circumferences of Circles (By Eighths from 5–11)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
5.	15.7080	19.635	7.	21.9911	38.485	9.	28.2743	63.617
1/8	16.1007	20.629	1/8	22.3838	39.871	1/8	28.6670	65.397
1/4	16.4934	21.648	1/4	22.7765	41.282	1/4	29.0597	67.201
3/8	16.8861	22.691	3/8	23.1692	42.718	3/8	29.4524	69.029
1/2	17.2788	23.758	1/2	23.5619	44.179	1/2	29.8451	70.882
5/8	17.6715	24.850	5/8	23.9546	45.664	5/8	30.2378	72.760
3/4	18.0642	25.967	3/4	24.3473	47.173	3/4	30.6305	74.662
7/8	18.4569	27.109	7/8	24.7400	48.707	7/8	31.0232	76.589
6.	18.8496	28.274	8.	25.1327	50.265	10.	31.4159	78.540
1/8	19.2423	29.465	1/8	25.5254	51.849	1/8	31.8086	80.516
1/4	19.6350	30.680	1/4	25.9181	53.456	1/4	32.2013	82.516
3/8	20.0277	31.919	3/8	26.3108	55.088	3/8	32.5940	84.541
1/2	20.4204	33.183	1/2	26.7035	56.745	1/2	32.9867	86.590
5/8	20.8131	34.472	5/8	27.0962	58.426	5/8	33.3794	88.664
3/4	21.2058	35.785	3/4	27.4889	60.132	3/4	33.7721	90.763
7/8	21.5984	37.122	7/8	27.8816	61.862	7/8	34.1648	92.886
7.	21.9911	38.485	9.	28.2743	63.617	11.	34.5575	95.933

CIRCUMFERENCES AND AREAS OF CIRCLES (1-150)

Diameter	Circumference ○	Area ●	Diameter	Circumference ○	Area ●	Diameter	Circumference ○	Area ●
1	3.1416	0.7854	51	160.22	2042.8	101	317.30	8011.9
2	6.2832	3.1416	52	163.36	2123.7	102	320.44	8171.3
3	9.4248	7.0686	53	166.50	2206.2	103	323.58	8332.3
4	12.566	12.5664	54	169.65	2290.2	104	326.73	8494.9
5	15.708	19.6350	55	172.79	2375.8	105	329.87	8659.0
6	18.850	28.2743	56	175.93	2463.0	106	333.01	8824.7
7	21.991	38.4845	57	179.07	2551.8	107	336.15	8992.0
8	25.133	50.2655	58	182.21	2642.1	108	339.29	9160.9
9	28.274	63.6173	59	185.35	2734.0	109	342.43	9331.3
10	31.416	78.54	60	188.50	2827.4	110	345.58	9503.3
11	34.558	95.03	61	191.64	2922.5	111	348.72	9676.9
12	37.699	113.10	62	194.78	3019.1	112	351.86	9852.0
13	40.841	132.73	63	197.92	3117.2	113	355.00	10028.8
14	43.982	153.94	64	201.06	3217.0	114	358.14	10207.0
15	47.124	176.71	65	204.20	3318.3	115	361.28	10386.9
16	50.265	201.06	66	207.35	3421.2	116	364.42	10568.3
17	53.407	226.98	67	210.49	3525.7	117	367.57	10751.3
18	56.549	254.47	68	213.63	3631.7	118	370.71	10935.9
19	59.690	283.53	69	216.77	3739.3	119	373.85	11122.0
20	62.832	314.16	70	219.91	3848.5	120	376.99	11310
21	65.973	346.36	71	223.05	3959.2	121	380.13	11499
22	69.115	380.13	72	226.19	4071.5	122	383.27	11690
23	72.257	415.48	73	229.34	4185.4	123	386.42	11882
24	75.398	452.39	74	232.48	4300.8	124	389.56	12076
25	78.540	490.87	75	235.62	4417.9	125	392.70	12272
26	81.681	530.93	76	238.76	4536.5	126	395.84	12469
27	84.823	572.56	77	241.90	4656.6	127	398.98	12668
28	87.965	615.75	78	245.04	4778.4	128	402.12	12868
29	91.106	660.52	79	248.19	4901.7	129	405.27	13070
30	94.248	706.86	80	251.33	5026.6	130	408.41	13273
31	97.389	754.77	81	254.47	5153.0	131	411.55	13478
32	100.53	804.25	82	257.61	5281.0	132	414.69	13685
33	103.67	855.30	83	260.75	5410.6	133	417.83	13893
34	106.81	907.92	84	263.89	5541.8	134	420.97	14103
35	109.96	962.11	85	267.04	5674.5	135	424.12	14314
36	113.10	1017.88	86	270.18	5808.8	136	427.26	14527
37	116.24	1075.21	87	273.32	5944.7	137	430.40	14741
38	119.38	1134.11	88	276.46	6082.1	138	433.54	14957
39	122.52	1194.59	89	279.60	6221.1	139	436.68	15175
40	125.66	1256.63	90	282.74	6361.7	140	439.82	15394
41	128.81	1320.25	91	285.88	6503.9	141	442.96	15615
42	131.95	1385.44	92	289.03	6647.6	142	446.11	15837
43	135.09	1452.20	93	292.17	6792.9	143	449.25	16061
44	138.23	1520.56	94	295.31	6939.8	144	452.39	16286
45	141.37	1590.43	95	298.45	7088.2	145	455.53	16513
46	144.51	1661.90	96	301.59	7238.2	146	458.67	16742
47	147.65	1734.94	97	304.73	7389.8	147	461.81	16972
48	150.80	1809.55	98	307.88	7543.0	148	464.96	17203
49	153.94	1885.74	99	311.02	7697.7	149	468.10	17437
50	157.08	1963.50	100	314.16	7854.0	150	471.24	17671

AREAS AND CIRCUMFERENCES OF CIRCLES (BY TENTHS UP TO 18)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
0.0	.00000	.000000	6.0	18.8496	28.2743	12.0	37.6991	113.0973
.1	.31416	.007854	.1	19.1637	29.2247	.1	38.0133	114.9901
.2	.62832	.031416	.2	19.4779	30.1907	.2	38.3274	116.8987
.3	.94248	.070686	.3	19.7920	31.1725	.3	38.6416	118.8229
.4	1.2566	.12566	.4	20.1062	32.1699	.4	38.9557	120.7628
.5	1.5708	.19635	.5	20.4204	33.1831	.5	39.2699	122.7185
.6	1.8850	.28274	.6	20.7345	34.2119	.6	39.5841	124.6898
.7	2.1991	.38485	.7	21.0487	35.2565	.7	39.8982	126.6769
.8	2.5133	.50266	.8	21.3628	36.3168	.8	40.2124	128.6796
.9	2.8274	.63617	.9	21.6770	37.3928	.9	40.5265	130.6981
1.0	3.1416	.7854	7.0	21.9911	38.4845	13.0	40.8407	132.7323
.1	3.4558	.9503	.1	22.3053	39.5919	.1	41.1549	134.7822
.2	3.7699	1.1310	.2	22.6195	40.7150	.2	41.4690	136.8478
.3	4.0841	1.3273	.3	22.9336	41.8539	.3	41.7832	138.9291
.4	4.3982	1.5394	.4	23.2478	43.0084	.4	42.0973	141.0261
.5	4.7124	1.7671	.5	23.5619	44.1786	.5	42.4115	143.1388
.6	5.0265	2.0106	.6	23.8761	45.3646	.6	42.7257	145.2672
.7	5.3407	2.2698	.7	24.1903	46.5663	.7	43.0398	147.4114
.8	5.6549	2.5447	.8	24.5044	47.7836	.8	43.3540	149.5712
.9	5.9690	2.8353	.9	24.8186	49.0167	.9	43.6681	151.7468
2.0	6.2832	3.1416	8.0	25.1327	50.2655	14.0	43.9823	153.9380
.1	6.5973	3.4636	.1	25.4469	51.5300	.1	44.2965	156.1450
.2	6.9115	3.8013	.2	25.7611	52.8102	.2	44.6106	158.3677
.3	7.2257	4.1548	.3	26.0752	54.1061	.3	44.9248	160.6061
.4	7.5398	4.5239	.4	26.3894	55.4177	.4	45.2389	162.8602
.5	7.8540	4.9087	.5	26.7035	56.7450	.5	45.5531	165.1300
.6	8.1681	5.3093	.6	27.0177	58.0880	.6	45.8673	167.4155
.7	8.4823	5.7256	.7	27.3319	59.4468	.7	46.1814	169.7167
.8	8.7965	6.1575	.8	27.6460	60.8212	.8	46.4956	172.0336
.9	9.1106	6.6052	.9	27.9602	62.2114	.9	46.8097	174.3662
3.0	9.4248	7.0686	9.0	28.2743	63.6173	15.0	47.1239	176.7146
.1	9.7389	7.5477	.1	28.5885	65.0388	.1	47.4380	179.0786
.2	10.0531	8.0425	.2	28.9027	66.4761	.2	47.7522	181.4584
.3	10.3673	8.5530	.3	29.2168	67.9291	.3	48.0664	183.8539
.4	10.6814	9.0792	.4	29.5310	69.3978	.4	48.3805	186.2650
.5	10.9956	9.6211	.5	29.8451	70.8822	.5	48.6947	188.6919
.6	11.3097	10.1788	.6	30.1593	72.3823	.6	49.0088	191.1345
.7	11.6239	10.7521	.7	30.4734	73.8981	.7	49.3230	193.5928
.8	11.9381	11.3411	.8	30.7876	75.4296	.8	49.6372	196.0668
.9	12.2522	11.9459	.9	31.1018	76.9769	.9	49.9513	198.5565
4.0	12.5664	12.5664	10.0	31.4159	78.5398	16.0	50.2655	201.0619
.1	12.8805	13.2025	.1	31.7301	80.1185	.1	50.5796	203.5831
.2	13.1947	13.8544	.2	32.0442	81.7128	.2	50.8938	206.1199
.3	13.5088	14.5220	.3	32.3584	83.3229	.3	51.2080	208.6724
.4	13.8230	15.2053	.4	32.6726	84.9487	.4	51.5221	211.2407
.5	14.1372	15.9043	.5	32.9867	86.5901	.5	51.8363	213.8246
.6	14.4513	16.6190	.6	33.3009	88.2473	.6	52.1504	216.4243
.7	14.7655	17.3494	.7	33.6150	89.9202	.7	52.4646	219.0397
.8	15.0796	18.0956	.8	33.9292	91.6088	.8	52.7788	221.6708
.9	15.3938	18.8574	.9	34.2434	93.3132	.9	53.0929	224.3176
5.0	15.7080	19.6350	11.0	34.5575	95.0332	17.0	53.4071	226.9801
.1	16.0221	20.4282	.1	34.8717	96.7689	.1	53.7212	229.6583
.2	16 3363	21.2372	.2	35.1858	98.5203	.2	54.0354	232.3522
.3	16.6504	22.0618	.3	35.5000	100.2875	.3	54.3495	235.0618
.4	16.9646	22.9022	.4	35.8142	102.0703	.4	54.6637	237.7871
.5	17.2788	23.7583	.5	36.1283	103.8689	.5	54.9779	240.5282
.6	17.5929	24.6301	.6	36.4425	105.6832	.6	55.2920	243.2849
.7	17.9071	25.5176	.7	36.7566	107.5132	.7	55.6062	246.0574
.8	18.2212	26.4208	.8	37.0708	109.3588	.8	55.9203	248.8456
.9	18.5354	27.3397	.9	37.3850	111.2202	.9	56.2345	251.6494
6.0	18.8496	28.2743	12.0	37.6991	113.0973	18.0	56.5487	254.4690

SOLID BODIES

VOLUMES OF SOLIDS

CYLINDERS.—*Rule for Volume:* The volume of any cylinder is the area of one end, multiplied by the perpendicular distance to the other end.

Rule for Surface: The surface of any cylinder is equal to the circumference, measured perpendicularly to the sides, multiplied by the height, plus the area of the sum of the two ends.

PYRAMIDS.—*Rule for Volume:* The volume of a pyramid or cone is equal to one-third the area of the base multiplied by the perpendicular height.

Rule for Area of Surface: The area of the surface of a pyramid or cone, is one-half the circumference of the base multiplied by the slant height, plus the area of the base.

NOTE. For a pyramid the slant height is measured along the middle of one of the sides.

The area of a cone is also expressed as:

$$\frac{\text{Area of the base}}{\text{Radius of the base}} \text{ times the slant height}$$

SPHERES.—*Rule for Volume:* The volume of a sphere is equal to:

4/3 3.1416 times the radius cubed,
or 4.188 times the radius cubed,
or 1/6 the diameter times the area of the surface.

Rule for Area of the Surface: The area of the surface of a sphere is equal to:

4 times 3.1416 times the radius squared,
or 3.1416 times the diameter squared,
or 12.5664 times the radius squared.

Rule for Radius: The radius of a sphere is equal to

$0.62035 \sqrt[3]{\text{volume}}$,
or $\sqrt[3]{.07958 \text{ times the area of the surface}}$.

Rule for Circumference: The circumference of a sphere is:

$\sqrt[3]{59.217 \text{ times the volume}}$,
or $\sqrt{3.1416 \text{ times the area of the surface}}$.

WEDGE.—*Rule for Volume:* To twice the length of the base add the length of the edge, and multiply the sum by one-sixth of the product of the height of the wedge times the breadth of the base.

CONE.—*Rule for Volume:* Multiply the area of the base by one-third (1/3) of the altitude.

FRUSTRUMS OF PYRAMIDS AND CONES.—*Rule for Volume:* Multiply one-third of the perpendicular height, by the area of the top, plus the area of the base, plus the square root of the area of the top times the area of the base.

Rule for Area: Multiply one-half the slant height by the circumference of the top plus the circumference of the bottom.

CAPACITY OF A TANK.—To find the capacity of a tank: *Approximate rule:*

Square the diameter in feet and multiply by (0.147) and the result is barrels per foot.

Example:

Tank 30 feet in diameter.

$$
\begin{array}{r}
30 \times 30 = 900 \\
\underline{0.147} \\
132.3 \text{ bbls. per foot.}
\end{array}
$$

Another Rule: Square the diameter in feet, and multiply by half the height in inches. The result will give the total capacity in gallons.

TO FIND THE SAFE WORKING PRESSURE OF A BOILER OR TANK.—Multiply one-sixth of the tensile strength of the metal by the thickness of the plate used. Divide by one-half the diameter of the boiler or tank in inches, and the result is the safe working pressure in pounds per square inch.

WEIGHT PER SQUARE FOOT OF METAL.—One-inch iron weighs 40 pounds per square foot.

The thickness of the metal expressed decimally multiplied by 40 equals the weight per square foot.

Capacity of tank in United States gallons

5	725	1060	1440	1875	2380	2925	3550	4237	4960	5765	6698	7520	9516	11750	14215	16918	18358
6	870	1270	1728	2250	2855	3510	4260	5084	5952	6918	8038	9024	11419	14100	17059	20302	22030
7	1015	1480	2016	2625	3330	4095	4970	5931	6944	8071	9378	10528	13322	16450	19902	23680	25701
8	1160	1690	2304	3000	3805	4680	5680	6778	7936	9224	10718	12032	15225	18800	22745	27070	29372
9	1305	1900	2592	3375	4280	5265	6390	7625	8928	10377	12058	13536	17128	21150	25588	30454	33043
10	1450	2110	2880	3750	4755	5850	7100	8472	9920	11530	13398	15040	19031	23500	28431	33838	36714
11	1595	2320	3168	4125	5230	6435	7810	9319	10912	12683	14738	16544	20934	25850	31274	37222	40385
12	1740	2530	3456	4500	5705	7020	8520	10166	11904	13836	16078	18048	22837	28200	34117	40606	44056
13	1885	2740	3744	4875	6180	7605	9230	11013	12896	14989	17418	19552	24740	30550	36960	43990	47727
14	2030	2950	4032	5250	6655	8190	9940	11860	13888	16142	18758	21056	26643	32900	39803	47374	51398
15	2175	3160	4320	5625	7130	8775	10650	12707	14880	17295	20098	22260	28546	35250	42646	50758	55069
16	2320	3370	4608	6000	7605	9360	11360	13554	15872	18448	21438	24064	30449	37600	45489	54142	58740
17	2465	3580	4896	6375	8080	9945	12070	14401	16864	19601	22778	25568	32352	39950	48332	57520	62411
18	2610	3790	5184	6750	8535	10530	12780	15248	17856	20754	24118	27072	34255	42300	51175	60910	66082
19	2755	40000	5472	7125	9010	11115	13490	16095	18848	21907	25458	28576	36158	44650	54018	64294	69753
20	2900	4210	5760	7500	9490	11700	14200	16942	19840	23060	26798	30080	38062	47000	56861	67678	73484

CONTENTS, IN CUBIC FEET AND UNITED STATES GALLONS, OF PIPES AND CYLINDERS OF VARIOUS DIAMETERS AND ONE FOOT IN LENGTH

1 gallon = 231 cubic inches. 1 cubic foot = 7.4805 gallons.

Diameter in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity	Diameter in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity
1/4	.0003	.0025	....	6	.1963	1.469	61.13
5/16	.0005	.0040	....	6 1/8	.2046	1.531	58.65
3/8	.0008	.0057	....	6 1/4	.2131	1.594	56.31
7/16	.0010	.0078	....	6 3/8	.2217	1.662	54.01
1/2	.0014	.0102	....	6 1/2	.2304	1.724	52.08
9/16	.0017	.0129	....	6 5/8	.2394	1.791	50.13
5/8	.0021	.0159	....	6 3/4	.2485	1.859	48.29
11/16	.0026	.0193	....	6 7/8	.2578	1.928	46.55
3/4	.0031	.0230	....	7	.2673	1.999	44.89
13/16	.0036	.0269	....	7 1/8	.2769	2.071	43.34
7/8	.0042	.0312	....	7 1/4	.2867	2.145	41.86
15/16	.0048	.0359	....	7 3/8	.2967	2.219	40.45
1	.0055	.0408	2181.81	7 1/2	.3068	2.295	39.11
1 1/8	.0069	.0516	1739.13	7 5/8	.3171	2.373	37.84
1 1/4	.0085	.0638	1411.76	7 3/4	.3276	2.450	36.63
1 3/8	.0103	.0770	1165.04	7 7/8	.3382	2.530	35.48
1 1/2	.0123	.0918	975.69	8	.3491	2.611	34.37
1 5/8	.0144	.1077	833.33	8 1/8	.3601	2.694	33.32
1 3/4	.0167	.1249	718.56	8 1/4	.3712	2.777	32.33
1 7/8	.0192	.1436	625.00	8 3/8	.3826	2.862	31.36
2	.0218	.1632	550.44	8 1/2	.3941	2.948	30.45
2 1/8	.0246	.1840	487.80	8 5/8	.4057	3.035	29.58
2 1/4	.0276	.2066	434.76	8 3/4	.4176	3.125	28.74
2 3/8	.0308	.2304	389.52	8 7/8	.4296	3.214	27.93
2 1/2	.0341	.2550	351.84	9	.4418	3.305	27.16
2 5/8	.0376	.2813	319.14	9 1/8	.4541	3.397	26.43
2 3/4	.0412	.3085	291.26	9 1/4	.4667	3.491	25.71
2 7/8	.0451	.3374	266.07	9 3/8	.4794	3.586	25.03
3	.0491	.3672	244.39	9 1/2	.4922	3.682	24.38
3 1/8	.0533	.3987	225.14	9 5/8	.5053	3.780	23.75
3 1/4	.0576	.4309	208.33	9 3/4	.5185	3.879	23.14
3 3/8	.0621	.4645	193.23	9 7/8	.5319	3.979	22.56
3 1/2	.0668	.4998	178.14	10	.5454	4.080	22.00
3 5/8	.0717	.5361	167.36	10 1/8	.5591	4.182	21.46
3 3/4	.0767	.5738	156.45	10 1/4	.5730	4.286	20.94
3 7/8	.0819	.6127	146.52	10 3/8	.5871	4.392	20.44
4	.0873	.6528	137.43	10 1/2	.6013	4.498	19.96
4 1/8	.0928	.6942	129.31	10 5/8	.6157	4.606	19.49
4 1/4	.0985	.7369	121.82	10 3/4	.6303	4.715	19.04
4 3/8	.1044	.7810	114.94	10 7/8	.6450	4.825	18.60
4 1/2	.1104	.8263	108.69	11	.6600	4.937	18.18
4 5/8	.1167	.8727	102.82	11 1/8	.6751	5.050	17.78
4 3/4	.1231	.9206	97.50	11 1/4	.6903	5.164	17.38
4 7/8	.1296	.9695	92.59	11 3/8	.7057	5.279	17.00
5	.1364	1.020	87.98	11 1/2	.7213	5.396	16.63
5 1/8	.1433	1.072	83.74	11 5/8	.7370	5.513	16.28
5 1/4	.1503	1.125	79.84	11 3/4	.7530	5.633	15.94
5 3/8	.1576	1.179	76.14	11 7/8	.7691	5.753	15.60
5 1/2	.1650	1.234	72.73	12	.7854	5.875	15.28
5 5/8	.1726	1.291	69.52	12 1/8	.8018	5.998	14.94
5 3/4	.1803	1.349	66.56	12 1/4	.8184	6.122	14.66
5 7/8	.1883	1.409	63.72	12 3/8	.8352	6.248	14.37

(Continued)

CONTENTS, IN CUBIC FEET AND UNITED STATES GALLONS, OF PIPES AND CYLINDERS OF VARIOUS DIAMETERS AND ONE FOOT IN LENGTH

1 gallon = 231 cubic inches. 1 cubic foot = 7.4805 gallons.

Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity	Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity
12 1/2	.8522	6.375	14.080	21 1/4	2.463	18.42	4.872
12 5/8	.8693	6.503	13.800	21 1/2	2.521	18.86	4.760
12 3/4	.8866	6.632	13.530	21 3/4	2.580	19.30	4.651
12 7/8	.9041	6.763	13.270	22	2.640	19.75	4.545
13	.9218	6.895	13.020	22 1/4	2.700	20.20	4.445
13 1/8	.9395	7.028	12.780	22 1/2	2.761	20.66	4.347
13 1/4	.9575	7.163	12.530	22 3/4	2.823	21.12	4.251
13 3/8	.9757	7.299	12.300	23	2.885	21.58	4.160
13 1/2	.994	7.436	12.070	23 1/4	2.948	22.05	4.070
13 5/8	1.013	7.578	11.850	23 1/2	3.012	22.53	3.990
13 3/4	1.031	7.712	11.640	23 3/4	3.076	23.01	3.901
13 7/8	1.051	7.855	11.420	24	3.142	23.50	3.819
14	1.069	7.997	11.230	25	3.409	25.50	3.520
14 1/8	1.088	8.139	11.030	26	3.678	27.58	3.263
14 1/4	1.107	8.281	10.840	27	3.976	29.74	3.018
14 3/8	1.127	8.431	10.650	28	4.276	31.99	2.806
14 1/2	1.147	8.578	10.460	29	4.587	34.31	2.616
14 5/8	1.167	8.730	10.280	30	4.909	36.72	2.444
14 3/4	1.187	8.879	10.110	31	5.241	39.21	2.290
14 7/8	1.207	9.029	9.940	32	5.585	41.78	2.149
15	1.227	9.180	9.780	33	5.940	44.43	2.020
15 1/8	1.248	9.336	9.620	34	6.305	47.16	1.903
15 1/4	1.268	9.485	9.460	35	6.681	49.98	1.796
15 3/8	1.289	9.642	9.310	36	7.069	52.88	1.698
15 1/2	1.310	9.801	9.160	37	7.467	55.86	1.607
15 5/8	1.332	9.964	9.010	38	7.876	58.92	1.527
15 3/4	1.353	10.121	8.870	39	8.296	62.06	1.446
15 7/8	1.374	10.278	8.730	40	8.727	65.28	1.375
16	1.396	10.440	8.600	41	9.168	68.58	1.309
16 1/4	1.440	10.772	8.330	42	9.621	71.91	1.247
16 1/2	1.485	11.11	8.081	43	10.085	75.44	1.190
16 3/4	1.530	11.45	7.843	44	10.559	78.99	1.136
17	1.576	11.79	7.511	45	11.045	82.62	1.087
17 1/4	1.623	12.14	7.394	46	11.451	86.33	1.040
17 1/2	1.670	12.49	7.186	47	12.048	90.13	.996
17 3/4	1.718	12.85	6.985	48	12.566	94.00	.955
18	1.768	13.22	6.787	49	13.095	97.96	.916
18 1/4	1.817	13.59	6.604	50	13.635	102.00	.880
18 1/2	1.867	13.96	6.427	51	14.186	106.12	.846
18 3/4	1.917	14.34	6.259	52	14.748	110.32	.814
19	1.969	14.73	6.094	53	15.320	114.60	.783
19 1/4	2.021	15.12	5.938	54	15.904	118.97	.755
19 1/2	2.074	15.51	5.786	55	16.499	122.82	.727
19 3/4	2.128	15.92	5.639	56	17.104	127.95	.702
20	2.182	16.32	5.500	57	17.720	132.55	.677
20 1/4	2.237	16.73	5.365	58	18.347	137.24	.654
20 1/2	2.292	17.15	5.236	59	18.985	142.02	.632
20 3/4	2.348	17.56	5.110	60	19.635	146.89	.611
21	2.405	17.99	4.989				

To find the capacity of pipes greater than the largest given in the table, look in the table for a pipe one-half the given size and multiply its capacity by 4; or one of one-third its size, and multiply its capacity by 9, etc.

CONTENTS OF RECTANGULAR TANKS IN UNITED STATES GALLONS

For one foot in depth

Width of tank in feet	Length of tank in feet																		
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73	112.21	119.69	127.17	134.65	142.13	149.61	157.09	164.57
2½	......	46.75	56.10	65.45	74.80	84.16	93.51	102.86	112.21	121.56	130.91	140.26	149.61	158.96	168.31	177.66	187.01	196.36	205.71
3	......	......	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09	168.31	179.53	190.75	202.97	213.19	224.41	235.63	246.86
3½	......	......	......	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183.27	196.36	209.45	222.54	235.63	248.73	261.82	274.90	288.00
4	......	......	......	......	119.69	134.65	149.61	164.57	179.53	194.49	209.45	224.41	239.37	254.34	269.30	284.26	299.22	314.18	329.14
4½	......	......	......	......	......	151.48	168.31	185.14	201.97	218.80	235.63	252.47	269.30	286.13	302.96	319.79	336.62	353.45	370.28
5	......	......	......	......	......	......	187.01	205.71	224.41	243.11	261.82	280.52	299.22	317.92	336.62	355.32	374.03	392.72	411.43
5½	......	......	......	......	......	......	......	226.28	246.86	267.43	288.00	308.57	329.14	349.71	370.28	390.85	411.43	432.00	452.57
6	......	......	......	......	......	......	......	......	269.30	291.74	314.18	336.62	359.06	381.50	403.94	426.39	448.83	471.27	493.71
6½	......	......	......	......	......	......	......	......	......	316.05	340.36	364.67	388.98	413.30	437.60	461.92	486.23	510.54	534.85
7	......	......	......	......	......	......	......	......	......	......	366.54	392.72	418.91	445.09	471.27	497.45	523.64	549.81	575.99
7½	......	......	......	......	......	......	......	......	......	......	......	420.78	448.83	476.88	504.93	532.98	561.04	589.08	617.14
8	......	......	......	......	......	......	......	......	......	......	......	......	478.75	508.67	538.59	568.51	598.44	628.36	658.28
8½	......	......	......	......	......	......	......	......	......	......	......	......	......	540.46	572.25	604.05	635.84	667.63	699.42
9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	605.92	639.58	673.25	706.90	740.56
9½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	675.11	710.65	746.17	781.71
10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	748.05	785.45	822.86
10½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	824.73	864.00
11	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	905.14

WEIGHTS AND MEASURES

TROY WEIGHT.—24 grains = 1 pwt.; 20 pwts. = 1 ounce; 12 ounces = 1 pound. Used for weighing gold, silver and jewels.

APOTHECARIES' WEIGHT.—20 grains = 1 scruple; 3 scruples = 1 dram; 8 drams = 1 ounce; 12 ounces = 1 pound. The ounce and pound in this are the same as in Troy weight.

AVOIRDUPOIS WEIGHT.—27 11/32 grains = 1 dram; 16 drams = 1 ounce; 16 ounces = 1 pound; 100 pounds = 1 cwt.; 2000 pounds = 1 short ton; 2240 pounds = 1 long ton.

1 oz. Troy = 480 gr.; 1 oz. Av. = 437 1/2 gr.; 1 lb. Troy = 5760 gr.; 1 lb. Av. = 7000 gr.

DRY MEASURE.—2 pints = 1 quart; 8 quarts = 1 peck; 4 pecks = 1 bushel.

LIQUID MEASURE.—4 gills = 1 pint; 2 pints = 1 quart; 4 quarts = 1 gallon; 31 1/2 gallons = 1 barrel; 2 barrels = 1 hogshead. Barrels and hogsheads vary in size.

TIME MEASURE.—60 seconds = 1 minute; 60 minutes = 1 hour; 24 hours = 1 day; 7 days = 1 week; 28, 29, 30 or 31 days = 1 calendar month (30 days = 1 month in computing interest); 365 days = 1 year; 366 days = 1 leap year.

CIRCULAR MEASURE.—60 seconds = 1 minute; 60 minutes = 1 degree; 30 degrees = 1 sign; 90 degrees = 1 quadrant; 4 quadrants = 12 signs, or 360 degrees = 1 circle.

LONG MEASURE.—12 inches = 1 foot; 3 feet = 1 yard; 5 1/2 yards = 1 rod; 40 rods = 1 furlong; 8 furlongs = 1 stat. mile; 3 miles = 1 league.

MARINERS' MEASURE.—6 feet = 1 fathom; 120 fathoms = 1 cable length; 7 1/2 cable lengths = 1 mile; 5280 feet = 1 stat. mile; 6080 feet = 1 naut. mile (or a British Admiralty knot).

MISCELLANEOUS.—4 inches = 1 hand; 18 inches = 1 cubit; 21.8 inches = 1 Bible cubit; 2 1/2 feet = 1 military pace.

SQUARE MEASURE.—144 sq. inches = 1 sq. foot; 9 sq. feet = 1 sq. yard; 30 1/4 sq. yards = 1 sq. rod; 40 sq. rods = 1 rood; 4 roods = 1 acre; 640 acres = 1 sq. mile.

SURVEYORS' MEASURE.—7.92 inches = 1 link; 25 links = 1 rod; 4 rods = 1 chain; 10 sq. chains or 160 sq. rods = 1 acre; 640 acres = 1 sq. mile or section; 36 sq. miles (6 miles square) = 1 township.

CUBIC MEASURE.—1728 cubic inches = 1 cubic foot; 27 cubic feet = 1 cubic yard; 2150.42 cubic inches = 1 standard bushel; 231 cubic inches = 1 standard gallon; 1 cubic foot = about four-fifths of a bushel; 128 cubic feet = 1 cord (wood); 40 cubic feet = 1 ton (shipping).

METRIC EQUIVALENTS. Linear.—1 centimeter = 0.3937 inches; 1 decimeter = 3.937 inches = 0.328 ft.; 1 meter 39.37 inches = 1.0966 yards; 1 dekameter = 1.9884 rods; 1 kilometer = 0.62137 mile.

Square.—1 sq. centimeter = 0.1550 sq. in.; 1 sq. decimeter = 0.1076 sq. ft.; 1 sq. meter = 1.196 sq. yds.; 1 arc = 3954 sq. rods; 1 hectar = 247 acres; 1 sq. kilometer = 0.386 sq. mile.

Volume.—1 cubic centimeter = 0.061 cubic in.; 1 cubic decimeter = 0.0353 cubic ft.; 1 cubic meter, 1 stere = 1.308 cubic yds., 0.2759 cd.; 1 liter = 0.0908 qt. dry, 1.0567 qts. liq.; 1 dekaliter = 2.6417 gals., .135 peck; 1 hektoliter = 2.8375 bus.

WEIGHTS.—1 gram = 0.03527 ounce; 1 kilogram = 2.2046 lbs.; 1 metric ton = 1.1023 English tons (2000 pounds).

APPROXIMATE METRIC EQUIVALENTS.—1 decimeter = 4 inches; 1 meter = 1.1 yards; 1 kilometer = 5/8 of mile; 1 hectar = 2 1/2 acres; 1 stere, or cubic meter = 1/4 of a cord; 1 liter = 1.06 qts. liquid, 0.9 qt. dry; 1 hektoliter = 2 5/8 bushels; 1 kilogram = 2 1/5 lbs.; 1 metric ton = 2200 lbs.

COMPARATIVE TABLE

American and Foreign Weights and Measures

	Weights		Liquid Measures		Dry Measures	
	Name	U. S. Lbs. Av.	Name	U. S. Gals.	Name	U. S. Bush.
Austria	Pfund	= 1.235	Eimer	= 14.95	Nutze	= 1.745
Bremen	Pfund	= 1.099	Stubchen	= .851	Scheffel	= 2.103
Buenos Ayres	Libra	= 1.0127	Frasco	= .627	Fanega	= 3.894
China	Catty	= 1.3333			Sei	= 3.472
Cuba	Libra	= 1.0119	Arrobo	= 4.1	Fanega	= 3.124
Denmark	Pund	= 1.1025	Pott	= 1.255	Fonda	= 3.948
England	Pound	= 1.	Imp. Gal.	= 1.2003	Imp. Bu.	= 1.0315
France	Kilo	= 1.2046	Litre	= .2642	Hektolitre	= 2.838
Hamburg	Pfund	= 1.0683	Ohm	= 38.278	Fass	= 1.56
Japan	Monme	= 3.858	Masa	= .459		
Mexico	Libra	= 1.0119	Frasco	= .4	Fanega	= 1.547
Norway or Sweden	Skalpund	= .937	Kamea	= .662		
Papal State	Libbra	= .7475	Barile (w'e)	= 15.412	Rubblio	= .836
Portugal	Libra	= 1.0119	Almude	= 4.422	Alqueire	= .393
Russia	Fuat	= 1.097	Vedro	= 3.249	Chetviert	= 5.956
Turkey	Oke	= 2.834			Kilo	= 1.001

TABLE OF DECIMAL EQUIVALENTS OF THE FRACTION OF AN INCH

By 8ths, 16ths, 32ds, and 64ths.

8ths.	32ds.	64ths.	64ths continued.
1/8 =.125	1/32=.03125	1/64=.015625	33/64=.515625
1/4 =.250	3/32=.09375	3/64=.046875	35/64=.546875
3/8 =.375	5/32=.15625	5/64=.078125	37/64=.578125
1/2 =.500	7/32=.21875	7/64=.109375	39/64=.609375
5/8 =.625	9/32=.28125	9/64=.140625	41/64=.640625
3/4 =.750	11/32=.34375	11/64=.171875	43/64=.671875
7/8 =.875	13/32=.40625	13/64=.203125	45/64=.703125
16ths.	15/32=.46875	15/64=.234375	47/64=.734375
1/16=.0625	17/32=.53125	17/64=.265625	49/64=.765625
3/16=.1875	19/32=.59375	19/64=.296875	51/64=.796875
5/16=.3125	21/32=.65625	21/64=.328125	53/64=.828125
7/16=.4375	23/32=.71875	23/64=.359375	55/64=.859375
9/16=.5625	25/32=.78125	25/64=.390625	57/64=.890625
11/16=.6875	27/32=.84375	27/64=.421875	59/64=.921875
13/16=.8125	29/32=.90625	29/64=.453125	61/64=.953125
15/16=.9375	31/32=.96875	31/64=.484375	63/64=.984375

TABLE OF DECIMAL EQUIVALENTS OF THE FRACTION OF AN INCH

By 64ths; from 1–64 to 1 inch.

Fraction.	Decimal.	Fraction.	Decimal.	Fraction.	Decimal.	Fraction.	Decimal.
1/64	.015625	17/64	.265625	33/64	.515625	49/64	.765625
1/32	.031250	9/32	.281250	17/32	.531250	25/32	.781250
3/64	.046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.062500	5/16	.312500	9/16	.562500	13/16	.812500
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.093750	11/32	.343750	19/32	.593750	27/32	.843750
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.125000	3/8	.375000	5/8	.625000	7/8	.875000
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.156250	13/32	.406250	21/32	.656250	29/32	.902250
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.187500	7/16	.437500	11/16	.687500	15/16	.937500
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.218750	15/32	.468750	23/32	.718750	31/32	.968750
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375
1/4	.250000	1/2	.500000	3/4	.750000	1	1.000000

CONVERSION TABLES FOR CHANGING UNITED STATES GALLONS TO LITRES, OR FOR CHANGING LITRES TO UNITED STATES GALLONS

Conversion of United States Gallons into Litres

Gallons	0	1	2	3	4	5	6	7	8	9
	Litres	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*
0	0.0000	3.7853	7.5706	11.356	15.141	18.946	22.712	26.497	30.282	34.068
10	37.853	41.638	45.423	49.209	52.994	56.799	60.565	64.350	68.135	71.921
20	75.706	79.491	83.276	87.062	90.847	94.652	98.418	102.20	105.99	109.77
30	113.56	117.34	121.13	124.92	128.66	132.50	136.27	140.06	143.84	147.63
40	151.42	155.22	158.99	162.78	166.56	170.36	174.13	177.92	181.70	185.49
50	189.46	193.24	197.03	200.82	204.60	208.40	212.17	215.96	219.74	223.53
60	227.12	230.90	234.69	238.48	242.26	246.06	249.83	253.62	257.40	261.19
70	264.97	268.75	272.54	276.33	280.11	283.91	286.68	291.47	295.25	299.04
80	302.82	306.60	310.39	314.18	317.96	321.76	324.53	329.32	333.10	336.89
90	340.68	344.46	348.25	352.04	355.82	359.62	363.39	367.18	370.96	374.75
100	378.53	382.31	386.10	389.89	393.67	397.47	401.24	405.03	408.81	412.60

CONVERSION TABLES FOR CHANGING UNITED STATES GALLONS TO LITRES, OR FOR CHANGING LITRES TO UNITED STATES GALLONS CONTINUED

Conversion of Litres into United States Gallons

Litres	0	1	2	3	4	5	6	7	8	9
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
0	0.0000	0.2642	0.5284	0.7925	1.0567	1.3209	1.5851	1.8492	2.1134	2.3776
10	2.6418	2.9060	3.1702	3.4343	3.6985	3.9627	4.2269	4.4910	4.7552	5.0194
20	5.2836	5.5478	5.8120	6.0761	6.3403	6.6045	6.8687	7.1328	7.3970	7.6612
30	7.9254	8.1896	8.4538	8.7179	8.9821	9.2463	9.5105	9.8746	10.030	10.303
40	10.567	10.831	11.095	11.360	11.624	11.888	12.152	12.416	12.680	12.945
50	13.209	13.473	13.737	14.002	14.266	14.530	14.794	15.058	15.322	15.587
60	15.851	16.115	16.379	16.644	16.908	17.172	17.436	17.700	17.964	18.229
70	18.492	18.756	19.020	19.284	19.549	19.813	20.077	20.341	20.605	20.870
80	21.134	21.398	21.662	21.926	22.191	22.455	22.719	22.983	23.247	23.512
90	23.776	24.040	24.304	24.568	24.832	25.097	25.361	25.625	25.889	26.154
100	26.418	26.682	26.946	27.210	27.475	27.739	28.003	28.267	28.531	28.796

CONVERSION TABLES FOR CHANGING ENGLISH POUNDS TO KILOGRAMS, OR FOR CHANGING KILOGRAMS TO ENGLISH POUNDS THE METRIC SYSTEM

Conversion of English Pounds into Kilograms

English pounds	0	1	2	3	4	5	6	7	8	9
	Kilo.	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*
0	0.000	0.453	0.907	1.361	1.814	2.268	2.722	3.175	3.629	4.082
10	4.536	4.989	5.443	5.897	6.350	6.804	7.258	7.711	8.165	8.618
20	9.072	9.525	9.979	10.43	10.89	11.34	11.79	12.25	12.70	13.15
30	13.61	14.06	14.52	14.97	15.42	15.88	16.33	16.78	17.24	17.69
40	18.14	18.59	19.05	19.50	19.95	20.41	20.86	21.31	21.77	22.22
50	22.68	23.13	23.59	24.04	24.49	24.95	25.40	25.85	26.31	26.76
60	27.22	27.67	28.13	28.58	29.03	29.49	29.94	30.39	30.85	31.30
70	31.75	32.20	32.66	33.11	33.56	34.02	34.47	34.92	35.38	35.83
80	36.29	36.74	37.20	37.65	38.10	38.56	39.01	39.46	39.92	40.37
90	40.82	41.27	41.73	42.18	42.63	43.09	43.54	43.99	44.45	44.90
100	45.36	45.81	46.27	46.72	47.17	47.63	48.08	48.53	48.99	49.44

Conversion of Kilograms into English Pounds

Fr. kilo.	0	1	2	3	4	5	6	7	8	9
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	0.000	2.205	4.410	6.615	8.820	11.02	13.23	15.43	17.64	19.84
10	22.05	24.25	26.46	28.67	30.87	33.07	35.28	37.48	39.69	41.89
20	44.10	46.30	48.51	50.72	52.92	55.12	57.33	59.53	61.74	63.94
30	66.15	68.35	70.56	72.77	74.97	77.17	79.38	81.58	83.79	85.99
40	88.20	90.40	92.61	94.82	97.02	99.22	101.4	103.6	105.8	108.0
50	110.2	112.5	114.6	116.8	119.0	121.2	123.4	125.6	127.8	130.0
60	132.3	134.5	136.7	138.9	141.1	143.3	145.5	147.7	149.9	152.1
70	154.3	156.5	158.7	160.9	163.1	165.3	167.5	169.7	171.9	174.1
80	176.4	178.6	180.8	183.0	185.2	187.4	189.6	191.8	194.0	196.2
90	198.4	200.6	202.8	205.0	207.2	209.4	211.6	213.8	216.0	218.2
100	220.5	222.7	224.9	227.1	229.3	231.5	233.7	235.9	238.1	240 3

CLIMATIC TEMPERATURES.—The following table will prove of use in selecting lubricants with regard to their cold test and viscosity characteristics, for use in various sections of the country and in the writing of specifications, also for designing oil systems and storage.

CLIMATIC TEMPERATURES

Lowest and Average Degrees in the United States

(Compiled from United States Weather Bureau Records)

State	City	Lowest	*Av.
Ala.	Mobile	– 1	57.7
	Montgomery	– 5	56.1
Ariz.	Flagstaff	–17	34.8
	Phoenix	12	58.9
Ark.	Fort Smith	–15	49.5
	Little Rock	–12	52.0
Calif.	San Diego	32	57.2
	Independence	10	48.7
Col.	Denver	–29	38.4
	Grand Jct.	–16	39.2
Conn.	Hartford	–14	36.3
D. C.	Washington	–15	42.9
Fla.	Jupiter	24	69.8
	Jacksonville	10	60.9
Ga.	Savannah	8	57.2
	Atlanta	– 8	51.4
Idaho	Boise	–28	39.6
	Lewiston	–18	42.5
Ill.	Chicago	–23	35.9
	Springfield	–22	39.0
Ind.	Indianapolis	–25	40.4
	Evansville	–15	44.1
Ia.	Sioux City	– 3	32.1
	Keokuk	–24	37.6
Kan.	Ft. Dodge	–26	....
	Wichita	–22	42.9
Ky.	Louisville	–20	45.0
La.	New Orleans	7	60.5
	Shreveport	– 5	55.7
Me.	Eastport	–21	31.1
	Portland	–17	33.5
Md.	Baltimore	– 7	43.3
Mass.	Boston	–13	37.2
Mich.	Alpena	–27	29.1
	Detroit	–24	35.3
Minn.	Duluth	–41	25.5
	Minneapolis	–33	28.4
Miss.	Meridian	– 6	53.9
	Vicksburg	– 1	56.0
Mo.	Springfield	–29	43.0
	Hannibal	–20	39.7
Mont.	Havre	–55	27.7
	Helena	–42	30.9
Neb.	North Platte	–35	34.6
	Lincoln	–26	35.8
Nev.	Carson City	–22	....
	Winnemucca	–28	37.9
N. H.	Concord	..	33.1
N. J.	Atlantic City	– 7	41.6
N. Y.	Binghamton	–26	34.1
	New York City	– 6	40.1
N. M.	Roswell	–18	48.9
	Santa Fé	–13	38.0
N. C.	Hatteras	8	53.3
	Charlotte	– 5	49.8
N. D.	Devil's Lake	–51	18.9
N. D.	Bismarck	–44	23.5
Ohio	Toledo	–16	36.8
	Columbus	–20	39.8
Okla.	Oklahoma	–17	47.1
Ore.	Baker City	–20	34.1
	Portland	– 2	45.4
Pa.	Pittsburgh	–20	40.8
	Philadelphia	– 6	41.8
R. I.	Providence	–12	37.5
	Block Island	– 4	39.7
S. C.	Charleston	7	56.9
	Columbia	– 2	53.5
S. D.	Huron	–43	25.9
	Yankton	–32	31.2
Tenn.	Knoxville	–16	47.0
	Memphis	– 9	50.7
Tex.	Corpus Christi	11	62.7
	Fort Worth	– 8	49.5

* October 1st to May 1st. All stated in Fahrenheit.

CLIMATIC TEMPERATURES—Continued

Utah	Salt Lake City	–20	39.7
Vt.	Northfield	–32	27.8
Va.	Cape Henry	5	48.6
	Lynchburg	– 6	45.2
Wash.	Seattle	12	44.3
	Spokane	–30	37.0
W. Va.	Parkersburg	–27	41.9
	Elkins	–21	38.8
Wis.	La Crosse	–43	31.2
	Milwaukee	–25	32.4
Wyo.	Cheyenne	–38	33.7
	Landor	–36	29.0

THERMOMETER SCALES.—Fig. 1, Sec. 1, gives a graphic comparison of the Reaumur, Centigrade and Fahrenheit thermometer scales. The Reaumur scale, usually designated by the letter "R," is seldom used, except in Turkey, Egypt, Russia and Sweden. The 0 (zero) degree point on this scale is the temperature of melting ice, the same as the 0 (zero) point in the Centigrade scale. In the Reaumur scale, a temperature of 80 degrees corresponds to the temperature of boiling water, which is 100 degrees on the Centigrade scale, and 212 degrees on the Fahrenheit scale; that is, there are 80 degrees between the freezing point and the boiling point on the Reaumur scale.

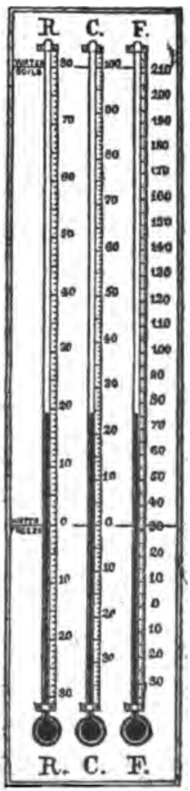

FIG. 1. SEC. 1.—Comparison of thermometer scales.

CONVERSION TABLES FOR CHANGING FAHRENHEIT THERMOMETER READINGS TO CENTIGRADE READINGS AND CENTIGRADE TO FAHRENHEIT

Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit
−273.00	−460.7	16	60.8	330	626	950	1742	1570	2858
−260.00	−436.0	17	62.6	340	644	960	1760	1580	2876
−250.00	−418.0	18	64.4	350	662	970	1778	1590	2894
−240.00	−400.0	19	66.2	360	680	980	1796	1600	2912
−230.00	−382.0	20	68.0	370	698	990	1814	1610	2930
−220.00	−364.0	21	69.8	380	716	1000	1832	1620	2948
−210.00	−346.0	22	71.6	390	734	1010	1850	1630	2966
−200.00	−328.0	23	73.4	400	752	1020	1868	1640	2984
−190.00	−310.0	24	75.2	410	770	1030	1886	1650	3002
−180.00	−292.0	25	77.0	420	788	1040	1904	1660	3020
−170.00	−274.0	26	78.8	430	806	1050	1922	1670	3038
−160.00	−256.0	27	80.6	440	824	1060	1940	1680	3056
−150.00	−238.0	28	82.4	450	842	1070	1958	1690	3074
−140.00	−220.0	29	84.2	460	860	1080	1976	1700	3092
−130.00	−202.0	30	86.0	470	878	1090	1994	1710	3110
−120.00	−184.0	31	87.8	480	896	1100	2012	1720	3128
−110.00	−166.0	32	89.6	490	914	1110	2030	1730	3146
−100.00	−148.0	33	91.4	500	932	1120	2048	1740	3164
− 90.00	−130.0	34	93.2	510	950	1130	2066	1750	3182
− 80.00	−112.0	35	95.0	520	968	1140	2084	1760	3200
− 70.00	− 94.0	36	96.8	530	986	1150	2102	1770	3218
− 60.00	− 76.0	37	98.6	540	1004	1160	2120	1780	3236
− 50.00	− 58.0	38	100.4	550	1022	1170	2138	1790	3254
− 40.00	− 40.0	39	102.2	560	1040	1180	2156	1800	3272
− 30.00	− 22.0	40	104.0	570	1058	1190	2174	1810	3290
− 20.00	− 4.0	41	105.8	580	1076	1200	2192	1820	3308
− 19.00	− 2.2	42	107.6	590	1094	1210	2210	1830	3326
− 18.00	− 0.4	43	109.4	600	1112	1220	2228	1840	3344
− 17.77	Zero	44	111.2	610	1130	1230	2246	1850	3362
− 17.00	+ 1.4	45	113.0	620	1148	1240	2264	1860	3380
− 16.00	+ 3.2	46	114.8	630	1166	1250	2282	1870	3398
− 15.00	+ 5.0	47	116.6	640	1184	1260	2300	1880	3416
− 14.00	+ 6.8	48	118.4	650	1202	1270	2318	1890	3434
− 13.00	+ 8.6	49	120.2	660	1220	1280	2336	1900	3452
− 12 00	+ 10.4	50	122.0	670	1238	1290	2345	1910	3470
− 11.00	+ 12.2	60	140.0	680	1256	1300	2372	1920	3488
− 10.00	+ 14.0	70	158.0	690	1274	1310	2390	1930	3506
− 9.00	+ 15.8	80	176.0	700	1292	1320	2408	1940	3524
− 8.00	+ 17.6	90	194.0	710	1310	1330	2426	1950	3542
− 7.00	+ 19.4	100	212.0	720	1328	1340	2444	1960	3560
− 6.00	+ 21.2	110	230.0	730	1346	1350	2462	1970	3578
− 5.00	+ 23.0	120	248.0	740	1364	1360	2480	1980	3596
− 4.00	+ 24.8	130	266.0	750	1382	1370	2498	1990	3614
− 3.00	+ 26.6	140	284.0	760	1400	1380	2516	2000	3632
− 2.00	+ 28.4	150	302.0	770	1418	1390	2534	2010	3650
− 1.00	+ 30.2	160	320.0	780	1436	1400	2552	2020	3668
Zero	+ 32.0	170	338.0	790	1454	1410	2570	2030	3686
+ 1	+ 33.8	180	356.0	800	1472	1420	2588	2040	3704
2	35.6	190	374.0	810	1490	1430	2606	2050	3722
3	37.4	200	392.0	820	1508	1440	2624	2060	3740
4	39.2	210	410.0	830	1526	1450	2642	2070	3758
5	41.0	220	428.0	840	1544	1460	2660	2080	3776
6	42.8	230	446.0	850	1562	1470	2678	2090	3794
7	44.6	240	464.0	860	1580	1480	2696	2100	3812
8	46.4	250	482.0	870	1598	1590	2714	2110	3830
9	48.2	260	500.0	880	1616	1500	2732	2120	3848
10	50.0	270	518.0	890	1634	1510	2750	2130	3866
11	51.8	280	536.0	900	1652	1520	2768	2140	3884
12	53.6	290	554.0	910	1670	1530	2786	2150	3902
13	55.4	300	572.0	920	1688	1540	2804	2160	3920
14	57.2	310	590.0	930	1706	1550	2822	2180	3956
15	59.0	320	608.0	940	1724	1560	2840	2200	3992

CONVERSION TABLES FOR CHANGING FAHRENHEIT THERMOMETER READINGS TO CENTIGRADE READINGS AND CENTIGRADE TO FAHRENHEIT

Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade
− 5	−20.55	57	13.88	119	48.33	181	82.77	243	117.22
− 4	−20.00	58	14.44	120	48.88	182	83.33	244	117.77
− 3	−19.44	59	15.00	121	49.44	183	83.88	245	118.33
− 2	−18.88	60	15.55	122	50.00	184	84.44	246	118.88
− 1	−18.33	61	16.11	123	50.55	185	85.00	247	119.44
Zero	−17.77	62	16.66	124	51.11	186	85.55	248	120.00
+ 1	−17.22	63	17.22	125	51.66	187	86.11	249	120.55
2	−16.66	64	17.77	126	52.22	188	86.66	250	121.11
3	−16.11	65	18.33	127	52.77	189	87.22	251	121.66
4	−15.55	66	18.88	128	53.55	190	87.77	252	122.22
5	−15.00	67	19.44	129	53.88	191	88.33	253	122.77
6	−14.44	68	20.00	130	54.44	192	88.88	254	123.33
7	−13.88	69	20.55	131	55.00	193	89.44	255	123.88
8	−13.33	70	21.11	132	55.55	194	90.00	256	124.44
9	−12.77	71	21.66	133	56.11	195	90.55	257	125.00
10	−12.22	72	22.22	134	56.66	196	91.11	258	125.55
11	−11.66	73	22.77	135	57.22	197	91.66	259	126.11
12	−11.11	74	23.33	136	57.77	198	92.22	260	126.66
13	−10.55	75	23.88	137	58.33	199	92.77	261	127.22
14	−10.00	76	24.44	138	58.88	200	93.33	262	127.77
15	− 9.44	77	25.00	139	59.44	201	93.88	263	128.33
16	− 8.88	78	25.55	140	60.00	202	94.44	264	128.88
17	− 8.33	79	26.11	141	60.55	203	95.00	265	129.44
18	− 7.77	80	26.66	142	61.11	204	95.55	266	130.00
19	− 7.22	81	27.22	143	61.66	205	96.11	267	130.55
20	− 6.66	82	27.77	144	62.22	206	96.66	268	131.11
21	− 6.11	83	28.33	145	62.77	207	97.22	269	131.66
22	− 5.55	84	28.88	146	63.33	208	97.77	270	132.22
23	− 5.00	85	29.44	147	63.88	209	98.33	271	132.77
24	− 4.44	86	30.00	148	64.44	210	98.88	272	133.33
25	− 3.88	87	30.55	149	65.00	211	99.44	273	133.88
26	− 3.33	88	31.11	150	65.55	212	100.00	274	134.44
27	− 2.77	89	31.66	151	66.11	213	100.55	275	135.00
28	− 2.22	90	32.22	152	66.66	214	101.11	276	135.55
29	− 1.66	91	32.77	153	67.22	215	101.66	277	136.11
30	− 1.11	92	33.33	154	67.77	216	102.22	278	136.66
31	− .55	93	33.88	155	68.33	217	102.17	279	137.22
32	Zero	94	34.44	156	68.88	218	103.33	280	137.77
33	+ .55	95	35.00	157	69.44	219	103.88	281	138.33
34	1.11	96	35.55	158	70.00	220	104.44	282	138.88
35	1.66	97	36.11	159	70.55	221	105.00	283	139.44
36	2.22	98	36.66	160	71.11	222	105.55	284	140.00
37	2.77	99	37.22	161	71.66	223	106.11	285	140.55
38	3.33	100	37.77	162	72.22	224	106.66	286	141.11
39	3.88	101	38.33	163	72.77	225	107.22	287	141.66
40	4.44	102	38.88	164	73.33	226	107.77	288	142.22
41	5.00	103	39.44	165	73.88	227	108.33	289	142.77
42	5.55	104	40.00	166	74.44	228	108.88	290	143.33
43	6.11	105	40.55	167	75.00	229	109.44	291	143.88
44	6.66	106	41.11	168	75.55	230	110.00	292	144.44
45	7.22	107	41.66	169	76.11	231	110.55	293	145.00
46	7.77	108	42.22	170	76.66	232	111.11	294	145.55
47	8.33	109	42.77	171	77.22	233	111.66	295	146.11
48	8.88	110	43.33	172	77.77	234	112.22	296	146.66
49	9.44	111	43.88	173	78.33	235	112.77	297	147.22
50	10.00	112	44.44	174	78.88	236	113.33	298	147.77
51	10.55	113	45.00	175	79.44	237	113.88	299	148.33
52	11.11	114	45.55	176	80.00	238	114.44	300	148.88
53	11.66	115	46.11	177	80.55	239	115.00	400	204.44
54	12.22	116	46.66	178	81.11	240	115.55	600	315.55
55	12.77	117	47.22	179	81.66	241	116.11	800	433.33
56	13.33	118	47.77	180	82.22	242	116.66	1000	537.77

MIXING PETROLEUM OILS TO OBTAIN A DESIRED GRAVITY.—An old refiner uses the following method to approximate the proportions of two oils to be blended to get a desired gravity:

Have gravity of 34*B and 22*B for two oils. A blend having 27*B is desired:

$$\begin{array}{ccc} 27 & & 34 \\ 22 & & 27 \\ \hline 5 & & 7 \end{array}$$

Equals 5 parts of the 34 gravity oil and 7 parts of the 22 gravity oil.

Proof:

$$\begin{array}{cc} 34 & 22 \\ 5 & 7 \\ \hline 170 & 154 \end{array}$$

$$\begin{array}{r} 7 \\ 5 \\ \hline 12 \end{array} \qquad \begin{array}{r} 154 \\ 170 \\ \hline 12\,)\,324\,(\,27^{*} \text{ gravity} \\ 24 \\ \hline 84 \\ 84 \\ \hline \end{array}$$

TO DIVIDE BY 7 1/2; A SHORT RULE.—If the total number of pounds of oil are known and it is desired to divide by 7 1/2 to get the number of gallons (approx.), the following rule may be used: Point off one point from the right of the number of pounds, divide by 3 and add.

Example:

Divide 435 by 7 1/2.

$$\begin{array}{lr} & 3\,)\,43.5 \\ \text{(adding)} & 14.5 \\ \hline & 58.0 \text{ answer} \end{array} \qquad \text{Proof: } \begin{array}{r} 7.5\,)\,435 \\ \hline 58.0 \text{ answer} \end{array}$$

SECTION 2

MARKETING

TRADE JOURNALS

Oil Trade Journals.—The following list gives the names and addresses of some well-known periodicals published for the oil trade:

Name	Office
Petroleum Review	111 Broadway, N. Y. English and foreign.
National Petroleum News	Caxton Building, Cleveland, Ohio; weekly.
Gulf Coast Oil News	Gulf Publishing Co., Inc., Foster Building, Houston, Texas; weekly.
Oil and Color Trades Journal	English office, Ludgate, London, E. C. 4. American office, 8 Broadway, N. Y.; weekly.
The Petroleum World	English office, 32 Great St. Helens, London, E. C. 3; monthly.
Oil, Paint and Drug Reporter	100 William St., N. Y.; weekly.
Oil and Gas News	210 Citizens Trust Building, Houston City, Mo.; monthly.
The Oil and Gas Journal	Tulsa, Okla.; weekly.
The Petroleum Age	20 West Jackson Boulevard, Chicago, Ill.
The Oil Trade Journal	120 Broadway, N. Y.; monthly.
Oil News	32 Great Saint Helens, London, E. C.
Oil City Derrick	Oil City, Pa.
Petroleum Gazette	Titusville, Pa.
California Oil World	Bakersfield, Calif.
California Derrick	San Francisco, Calif.
Oildom	Bayonne, N. J.
Le Moniteur du Petrole Roumain	Bucharest, Roumania.
Revue du Petrole	Bucharest, Roumania.
Neftianoie Dielo	Baku, Russia.
Naphtha	Lemberg, Russia.
Coalinga Oil Review	Coalinga, Calif.
The Oil Industry	San Francisco, Calif.
Along the Way	Titusville, Pa.
The American Oil Journal	Kansas City, Mo.
Independent Oil Items	Los Angeles, Calif.
Oil Age	Los Angeles, Calif.
Pacific Petroleum Record	Los Angeles, Calif.
Petroleum	Chicago, Il.
Oil and Gas Journal	Kansas City, Mo.
The Oil Weekly	Houston, Texas.
The Petroleum Journal	Wichita, Kan.
Tulsa Oil Review	Tulsa, Okla.
Tulsa World	Tulsa, Okla.

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
4	.264	.328	.5	.561	.697
.1	.271	.336	.6	.568	.705
.2	.277	.344	.7	.574	.713
.3	.284	.353	.8	.581	.722
.4	.290	.361	.9	.587	.730
.5	.297	.369	9	.594	.738
.6	.304	.377	.1	.601	.746
.7	.310	.385	.2	.607	.754
.8	.317	.394	.3	.614	.763
.9	.323	.402	.4	.620	.771
5	.330	.410	.5	.627	.779
.1	.337	.418	.6	.634	.787
.2	.343	.426	.7	.640	.795
.3	.350	.435	.8	.647	.804
.4	.357	.443	.9	.653	.812
.5	.363	.451	10	.660	.820
.6	.370	.459	.1	.667	.828
.7	.376	.467	.2	.673	.836
.8	.383	.476	.3	.680	.845
.9	.389	.484	.4	.686	.853
6	.396	.492	.5	.693	.861
.1	.403	.500	.6	.700	.869
.2	.409	.508	.7	.706	.877
.3	.416	.517	.8	.713	.886
.4	.422	.525	.9	.719	.894
.5	.429	.533	11	.726	.902
.6	.436	.541	.1	.733	.910
.7	.442	.549	.2	.739	.918
.8	.449	.558	.3	.746	.927
.9	.455	.566	.4	.752	.935
7	.462	.574	.5	.759	.943
.1	.469	.582	.6	.766	.951
.2	.475	.590	.7	.772	.959
.3	.482	.599	.8	.779	.968
.4	.488	.607	.9	.785	.976
.5	.495	.615	12	.792	.984
.6	.502	.623	.1	.799	.992
.7	.508	.631	.2	.805	1.000
.8	.515	.640	.3	.812	1.009
.9	.531	.648	.4	.818	1.017
8	.528	.656	.5	.825	1.025
.1	.535	.664	.6	.832	1.033
.2	.541	.672	.7	.838	1.041
.3	.548	.681	.8	.845	1.050
.4	.554	.689	.9	.851	1.058

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT—(Continued)

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
13	.858	1.066	.5	1.155	1.435
.1	.865	1.074	.6	1.162	1.443
.2	.871	1.032	.7	1.168	1.451
.3	.878	1.091	.8	1.175	1.460
.4	.884	1.099	.9	1.181	1.468
.5	.891	1.107	18	1.188	1.476
.6	.898	1.115	.1	1.195	1.484
.7	.904	1.123	.2	1.201	1.492
.8	.911	1.132	.3	1.208	1.501
.9	.917	1.140	.4	1.214	1.509
14	.924	1.148	.5	1.221	1.517
.1	.931	1.156	.6	1.228	1.525
.2	.937	1.164	.7	1.234	1.533
.3	.944	1.173	.8	1.241	1.542
.4	.950	1.181	.9	1.247	1.550
.5	.957	1.189	19	1.254	1.558
.6	.964	1.197	.1	1.261	1.566
.7	.970	1.205	.2	1.267	1.574
.8	.977	1.214	.3	1.274	1.583
.9	.983	1.222	.4	1.280	1.591
15	.990	1.230	.5	1.287	1.599
.1	.997	1.238	.6	1.294	1.607
.2	1.003	1.246	.7	1.300	1.615
.3	1.010	1.255	.8	1.307	1.624
.4	1.016	1.263	.9	1.313	1.632
.5	1.023	1.271	20	1.320	1.640
.6	1.030	1.279	.1	1.327	1.648
.7	1.036	1.287	.2	1.333	1.656
.8	1.043	1.296	.3	1.340	1.665
.9	1.049	1.304	.4	1.346	1.673
16	1.056	1.312	.5	1.353	1.681
.1	1.063	1.320	.6	1.360	1.689
.2	1.069	1.328	.7	1.366	1.697
.3	1.076	1.337	.8	1.373	1.706
.4	1.082	1.345	.9	1.379	1.714
.5	1.089	1.353	21	1.386	1.722
.6	1.096	1.361	.1	1.393	1.730
.7	1.102	1.369	.2	1.399	1.738
.8	1.109	1.378	.3	1.406	1.746
.9	1.115	1.386	.4	1.412	1.754
17	1.122	1.394	.5	1.419	1.763
.1	1.129	1.402	.6	1.426	1.771
.2	1.135	1.410	.7	1.432	1.778
.3	1.142	1.419	.8	1.439	1.788
.4	1.148	1.427	.9	1.445	1.796

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT—(Continued)

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
22	1.452	1.804	.5	1.749	2.173
.1	1.459	1.812	.6	1.756	2.181
.2	1.465	1.820	.7	1.762	2.189
.3	1.472	1.829	.8	1.769	2.198
.4	1.478	1.837	.9	1.775	2.206
.5	1.485	1.845	27	1.782	2.214
.6	1.492	1.853	.1	1.789	2.222
.7	1.498	1.861	.2	1.759	2.230
.8	1.505	1.869	.3	1.802	2.239
.9	1.511	1.878	.4	1.808	2.247
23	1.518	1.886	.5	1.815	2.255
.1	1.525	1.894	.6	1.822	2.263
.2	1.531	1.902	.7	1.828	2.271
.3	1.538	1.911	.8	1.835	2.280
.4	1.544	1.919	.9	1.841	2.288
.5	1.551	1.927	28	1.848	2.296
.6	1.558	1.535	.1	1.855	2.304
.7	1.564	1.943	.2	1.861	2.312
.8	1.571	1.952	.3	1.868	2.321
.9	1.577	1.960	.4	1.874	2.329
24	1.584	1.968	.5	1.881	2.337
.1	1.591	1.976	.6	1.888	2.345
.2	1.697	1.984	.7	1.894	2.353
.3	1.604	1.993	.8	1.901	2.362
.4	1.610	2.001	.9	1.907	2.370
.5	1.617	2.009	29	1.914	2.378
.6	1.624	2.017	.1	1.921	2.386
.7	1.630	2.025	.2	1.927	2.394
.8	1.637	2.033	.3	1.934	2.403
.9	1.643	2.042	.4	1.940	2.411
25	1.650	2.050	.5	1.947	2.419
.1	1.657	2.058	.6	1.954	2.427
.2	1.663	2.066	.7	1.960	2.435
.3	1.670	2.075	.8	1.967	2.443
.4	1.676	2.083	.9	1.973	2.452
.5	1.683	2.091	30	1.980	2.460
.6	1.690	2.099	.1	1.987	2.468
.7	1.696	2.107	.2	1.993	2.476
.8	1.703	2.116	.3	2.000	2.485
.9	1.709	2.124	.4	2.006	2.493
26	1.716	2.132	.5	2.013	2.501
.1	1.723	2.140	.6	2.020	2.509
.2	1.729	2.148	.7	2.026	2.517
.3	1.736	2.157	.8	2.033	2.526
.4	1.742	2.165	.9	2.039	2.534

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT—(Continued)

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
31	2.046	2.542	.6	2.350	2.919
.1	2.053	2.550	.7	2.356	2.927
.2	2.059	2.558	.8	2.363	2.936
.3	2.066	2.567	.9	2.369	2.944
.4	2.072	2.575	36	2.376	2.952
.5	2.079	2.583	.1	2.383	2.960
.6	2.086	2.591	.2	2.389	2.968
.7	2.092	2.599	.3	2.396	2.977
.8	2.099	2.608	.4	2.402	2.985
.9	2.105	2.616	.5	2.409	2.993
32	2.112	2.624	.6	2.416	3.001
.1	2.119	2.632	.7	2.422	3.009
.2	2.125	2.640	.8	2.429	3.018
.3	2.132	2.649	.9	2.439	3.026
.4	2.138	2.657	37	2.422	3.034
.5	2.145	2.665	.1	2.049	3.042
.6	2.152	2.673	.2	2.455	3.050
.7	2.158	2.681	.3	2.462	3.059
.8	2.165	2.690	.4	2.468	3.067
.9	2.171	2.698	.5	2.475	3.075
33	2.178	2.706	.6	2.482	3.083
.1	2.185	2.714	.7	2.488	3.091
.2	2.191	2.722	.8	2.495	3.100
.3	2.198	2.731	.9	2.501	3.108
.4	2.204	2.739	38	2.508	3.116
.5	2.211	2.747	.1	2.515	3.124
.6	2.218	2.755	.2	2.521	3.132
.7	2.234	2.763	.3	2.528	3.141
.8	2.231	2.772	.4	2.534	3.149
.9	2.237	2.780	.5	2.541	3.157
34	2.244	2.788	.6	2.547	3.165
.1	2.251	2.796	.7	2.554	3.173
.2	2.257	2.804	.8	2.561	3.182
.3	2.264	2.813	.9	2.567	3.190
.4	2.270	2.821	39	2.574	3.198
.5	2.277	2.829	.1	2.581	3.206
.6	2.284	2.837	.2	2.587	3.214
.7	2.290	2.845	.3	2.594	3.223
.8	2.297	2.854	.4	2.600	3.231
.9	2.303	2.802	.5	2.607	3.239
35	2.310	2.870	.6	2.614	3.247
.1	2.317	2.878	.7	2.620	3.255
.2	2.322	2.886	.8	2.627	3.264
.3	2.330	2.895	.9	2.633	3.272
.4	2.336	2.903	40	2.640	3.280
.5	2.343	2.911			

TABLE SHOWING FREIGHT COST IN CENTS PER GALLON ON OIL OF STATED WEIGHT PER BARREL, AT DETERMINED RATES PER HUNDRED POUNDS

(NOTE.—Barrels averaged at 50 Gallons each.)

Rate per 100 lbs.	Weight per barrel				Rate per 100 lbs.	Weight per barrel				Rate per 100 lbs.	Weight per barrel				Rate per 100 lbs.	Weight per barrel			
	410	400	330	320		410	400	330	320		410	400	330	320		410	400	330	320
.10	.01	.01	.01	.01	18	1.48	1.44	1.19	1.15	46	3.77	3.68	3.04	2.94	74	6.07	5.92	4.88	4.74
.20	.02	.02	.01	.01	19	1.56	1.52	1.25	1.22	47	3.85	3.76	3.10	3.01	75	6.15	6.00	4.95	4.80
.25	.02	.02	.02	.02	20	1.64	1.60	1.32	1.28	48	3.94	3.84	3.17	3.07	76	6.23	6.08	5.02	4.86
.30	.02	.02	.02	.02	21	1.72	1.68	1.39	1.34	49	4.02	3.92	3.23	3.14	77	6.31	6.16	5.08	4.93
.40	.03	.03	.03	.33	22	1.80	1.76	1.45	1.41	50	4.10	4.00	3.30	3.20	78	6.40	6.24	5.15	4.99
.50	.04	.04	.03	.03	23	1.89	1.84	1.52	1.47	51	4.18	4.08	3.37	3.26	79	6.48	6.32	5.21	5.06
.60	.05	.05	.04	.04	24	1.97	1.92	1.58	1.54	52	4.26	4.16	3.43	3.33	80	6.56	6.40	5.28	5.12
.70	.06	.06	.05	.04	25	2.05	2.00	1.65	1.60	53	4.35	4.24	3.50	3.39	81	6.64	6.48	5.35	5.18
.75	.06	.06	.05	.05	26	2.13	2.08	1.72	1.66	54	4.43	4.32	3.56	3.46	82	6.72	6.56	5.41	5.25
.80	.07	.06	.05	.05	27	2.21	2.16	1.78	1.73	55	4.51	4.40	3.63	3.52	83	6.81	6.64	5.48	5.31
.90	.07	.07	.06	.06	28	2.30	2.24	1.85	1.79	56	4.59	4.48	3.70	3.58	84	6.89	6.72	5.54	5.38
1	.08	.08	.07	.06	29	2.38	2.32	1.91	1.86	57	4.67	4.56	3.76	3.65	85	6.97	6.80	5.61	5.44
2	.16	.16	.13	.13	30	2.46	2.40	1.98	1.92	58	4.76	4.64	3.83	3.71	86	7.05	6.88	5.68	5.50
3	.25	.24	.20	.19	31	2.54	2.48	2.05	1.98	59	4.84	4.72	3.89	3.78	87	7.13	6.96	5.74	5.57
4	.33	.32	.26	.26	32	2.62	2.56	2.11	2.05	60	4.92	4.80	3.96	3.84	88	7.22	7.04	5.81	5.63
5	.41	.40	.33	.32	33	2.71	2.64	2.18	2.11	61	5.00	4.88	4.03	3.90	89	7.30	7.12	5.87	5.70
6	.49	.48	.40	.38	34	2.79	2.72	2.24	2.18	62	5.08	4.96	4.09	3.97	90	7.38	7.20	5.94	5.76
7	.57	.56	.46	.45	35	2.87	2.80	2.31	2.24	63	5.17	5.04	4.16	4.03	91	7.46	7.28	6.01	5.82
8	.66	.64	.53	.51	36	2.95	2.88	2.38	2.30	64	5.25	5.12	4.22	4.10	92	7.54	7.36	6.07	5.89
9	.74	.72	.59	.58	37	3.03	2.96	2.44	2.37	65	5.33	5.20	4.29	4.16	93	7.63	7.44	6.14	5.95
10	.82	.80	.66	.64	38	3.12	3.04	2.51	2.43	66	5.41	5.28	4.36	4.22	94	7.71	7.52	6.20	6.02
11	.90	.88	.73	.70	39	3.20	3.12	2.57	2.50	67	5.49	5.36	4.42	4.29	95	7.79	7.60	6.27	6.08
12	.98	.96	.79	.77	40	3.28	3.20	2.64	2.56	68	5.58	5.44	4.49	4.35	96	7.87	7.68	6.34	6.14
13	1.07	1.04	.86	.83	41	3.36	3.28	2.71	2.62	69	5.66	5.52	4.55	4.42	97	7.95	7.76	6.40	6.21
14	1.15	1.12	.92	.90	42	3.44	3.36	2.77	2.69	70	5.74	5.60	4.62	4.48	98	8.04	7.84	6.47	6.27
15	1.23	1.20	.99	.96	43	3.53	3.44	2.84	2.75	71	5.82	5.68	4.69	4.54	99	8.12	7.92	6.53	6.34
16	1.31	1.28	1.06	1.02	44	3.61	3.52	2.90	2.82	72	5.00	5.76	4.75	4.61	100	8.20	8.00	6.60	6.40
17	1.39	1.36	1.12	1.09	45	3.69	3.60	2.97	2.88	73	5.99	5.84	4.82	4.67					

MISCELLANEOUS PER TON FREIGHT RATES AND EQUIVALENT RATES PER GALLON

Per ton	Bulk per gallon	Wooden barrel per gallon
10	.033	.041
15	.050	.061
20	.066	.082
22 1/2	.074	.092
25	.083	.103
30	.099	.123
35	.116	.144
40	.132	.164
45	.149	.185
50	.165	.205
53	.175	.217
55	.182	.226
60	.198	.246
63	.208	.258
65	.215	.267
70	.231	.287
75	.248	.308
80	.264	.328

TABLE OF FREIGHT COST PER GALLON, AT DIFFERENT SHIPPING WEIGHTS BASED ON FREIGHT RATE PER HUNDRED POUNDS

Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.	Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.
3	.0020	.0022	.0025	25.5	.0168	.0189	.0209
3.5	.0023	.0027	.0029	26	.0171	.0192	.0213
4	.0026	.0029	.0033	26.5	.0175	.0196	.0217
4.5	.0030	.0032	.0037	27	.0178	.0200	.0221
5	.0033	.0037	.0041	27.5	.0182	.0204	.0226
5.5	.0036	.0040	.0045	28	.0185	.0207	.0230
6	.0040	.0044	.0049	28.5	.0188	.0211	.0234
6.5	.0043	.0048	.0053	29	.0191	.0215	.0238
7	.0046	.0052	.0057	29.5	.0195	.0218	.0242
7.5	.0050	.0055	.0062	30	.0198	.0222	.0246
8	.0053	.0059	.0066	30.5	.0201	.0226	.0250
8.5	.0055	.0063	.0070	31	.0205	.0229	.0254
9	.0059	.0067	.0074	31.5	.0208	.0233	.0258
9.5	.0063	.0070	.0078	32	.0211	.0237	.0262
10	.0066	.0074	.0082	32.5	.0215	.0241	.0267
10.5	.0069	.0078	.0086	33	.0218	.0244	.0271
11	.0073	.0081	.0090	33.5	.0221	.0248	.0275
11.5	.0076	.0085	.0094	34	.0224	.0252	.0279
12	.0079	.0089	.0098	34.5	.0228	.0255	.0283
12.5	.0083	.0093	.0103	35	.0231	.0259	.0287
13	.0086	.0096	.0107	35.5	.0234	.0263	.0291
13.5	.0089	.0100	.0111	36	.0238	.0266	.0295
14	.0092	.0104	.0115	36.5	.0241	.0270	.0299
14.5	.0096	.0107	.0119	37	.0244	.0274	.0303
15	.0099	.0111	.0123	37.5	.0248	.0278	.0308
15.5	.0102	.0115	.0127	38	.0251	.0281	.0312
16	.0105	.0118	.0131	38.5	.0254	.0285	.0316
16.5	.0109	.0122	.0135	39	.0257	.0289	.0320
17	.0112	.0126	.0139	39.5	.0261	.0292	.0324
17.5	.0116	.0130	.0144	40	.0264	.0296	.0328
18	.0119	.0133	.0148	40.5	.0267	.0300	.0332
18.5	.0122	.0137	.0152	41	.0271	.0303	.0336
19	.0125	.0141	.0156	41.5	.0274	.0307	.0340
19.5	.0129	.0144	.0160	42	.0277	.0311	.0344
20	.0132	.0148	.0164	42.5	.0281	.0315	.0349
20.5	.0135	.0152	.0168	43	.0284	.0318	.0353
21	.0139	.0155	.0172	43.5	.0287	.0322	.0357
21.5	.0142	.0159	.0176	44	.0290	.0326	.0361
22	.0145	.0163	.0180	44.5	.0294	.0329	.0365
22.5	.0149	.0167	.0185	45	.0297	.0333	.0369
23	.0152	.0170	.0189	45.5	.0300	.0337	.0373
23.5	.0155	.0174	.0193	46	.0303	.0340	.0377
24	.0158	.0178	.0197	46.5	.0307	.0344	.0381
24.5	.0162	.0181	.0201	47	.0310	.0348	.0385
25	.0165	.0185	.0205	47.5	.0314	.0352	.0390

TABLE OF FREIGHT COST PER GALLON, AT DIFFERENT SHIPPING WEIGHTS BASED ON FREIGHT RATE PER HUNDRED POUNDS—(Continued)

Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.	Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.
48	.0317	.0355	.0394	70.5	.0465	.0522	.0578
48.5	.0320	.0359	.0398	71	.0469	.0524	.0582
49	.0323	.0363	.0402	71.5	.0472	.0529	.0586
49.5	.0327	.0366	.0406	72	.0475	.0533	.0590
50	.0330	.0370	.0410	72.5	.0479	.0537	.0595
50.5	.0333	.0374	.0414	73	.0482	.0540	.0599
51	.0337	.0377	.0418	73.5	.0485	.0544	.0603
51.5	.0340	.0381	.0422	74	.0488	.0548	.0607
52	.0343	.0385	.0426	74.5	.0492	.0551	.0611
52.5	.0347	.0389	.0431	75	.0495	.0555	.0615
53	.0350	.0392	.0435	75.5	.0498	.0559	.0619
53.5	.0353	.0396	.0439	76	.0501	.0562	.0623
54	.0356	.0400	.0443	76.5	.0504	.0566	.0627
54.5	.0360	.0403	.0447	77	.0508	.0570	.0631
55	.0363	.0407	.0451	77.5	.0512	.0574	.0636
55.5	.0366	.0411	.0455	78	.0515	.0577	.0640
56	.0370	.0414	.0459	78.5	.0518	.0581	.0644
56.5	.0373	.0418	.0463	79	.0520	.0585	.0648
57	.0376	.0422	.0467	79.5	.0524	.0588	.0652
57.5	.0380	.0426	.0472	80	.0528	.0592	.0656
58	.0383	.0429	.0476	80.5	.0531	.0596	.0660
58.5	.0386	.0432	.0480	81	.0535	.0599	.0664
59	.0389	.0437	.0484	81.5	.0538	.0603	.0668
59.5	.0393	.0440	.0488	82	.0541	.0607	.0672
60	.0396	.0444	.0492	82.5	.0545	.0611	.0677
60.5	.0399	.0448	.0496	83	.0548	.0614	.0681
61	.0403	.0451	.0500	83.5	.0551	.0618	.0685
61.5	.0406	.0455	.0504	84	.0554	.0622	.0689
62	.0409	.0459	.0508	84.5	.0558	.0625	.0693
62.5	.0413	.0463	.0513	85	.0561	.0629	.0697
63	.0416	.0466	.0517	85.5	.0564	.0633	.0701
63.5	.0419	.0470	.0521	86	.0568	.0636	.0705
64	.0422	.0474	.0525	86.5	.0571	.0640	.0709
64.5	.0426	.0477	.0529	87	.0574	.0644	.0713
65	.0429	.0481	.0533	87.5	.0578	.0648	.0718
65.5	.0432	.0485	.0537	88	.0581	.0651	.0722
66	.0436	.0488	.0541	88.5	.0584	.0655	.0726
66.5	.0439	.0492	.0545	89	.0587	.0659	.0730
67	.0442	.0496	.0549	89.5	.0591	.0662	.0734
67.5	.0446	.0500	.0554	90	.0594	.0666	.0738
68	.0449	.0503	.0558	90.5	.0597	.0670	.0742
68.5	.0452	.0507	.0562	91	.0601	.0673	.0746
69	.0455	.0511	.0566	91.5	.0604	.0677	.0750
69.5	.0459	.0514	.0570	92	.0607	.0681	.0754

TABLE OF FREIGHT COST PER GALLON AT DIFFERENT SHIPPING WEIGHTS BASED ON FREIGHT RATE PER HUNDRED POUNDS—(Continued)

Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.	Rate Cents Cwt.	Cost @ 6.6 Lb.	Cost @ 7.4 Lb.	Cost @ 8.2 Lb.
93	.0614	.0688	.0763	97	.0640	.0718	.0795
93.5	.0617	.0692	.0767	97.5	.0644	.0721	.0800
94	.0620	.0696	.0771	98	.0647	.0725	.0804
94.5	.0624	.0699	.0775	98.5	.0650	.0729	.0808
95	.0627	.0703	.0779	99	.0653	.0733	.0812
95.5	.0630	.0706	.0783	99.5	.0657	.0736	.0816
96	.0634	.0710	.0787	100	.0660	.0740	.0820
96.5	.0637	.0714	.0791				

SHIPPING WEIGHT NOTES

DISPLACEMENT OF OIL PACKED TO SHIP.

The U. S. Bureau of Standards, Department of Commerce, has compiled a table on the displacement of various commodities as packed for overseas shipment, showing the number of pounds per cubic foot, number of cubic feet of space required for a short and a long ton, and the manner in which the material is packed for shipment. The table includes the following relative to crude and refined oil:

Crude: 51 pounds per cubic foot as packed for shipment; 39 cubic feet of space required per short ton, and 44 cubic feet per long ton; averages 330 gallons per long ton as shipped in tanks or tank cars.

Refined: 58 pounds per cubic foot as packed for shipment; 35 cubic feet of space required per short ton, and 39 cubic feet per long ton; averages 300 gallons per long ton as shipped in tanks or tank cars, with 4 per cent. increase in volume with increase in temperature from 32° to 120° F.

Rules for Changing Kilograms to U. S. Gallons.—(*a*) Refer to Table on page 28 and change the kilograms to pounds.

(*b*) Take the gravity of the oil.

(*c*) Refer to Gravity-weight Table (see Index) and pick out the weight corresponding to that gravity.

(*d*) Divide the weight in pounds per gallon into the number of pounds as determined at (*a*), and the result will be in U. S. gallons.

An approximate result may be obtained when changing kilograms to U. S. gallons by the following formula:

0.295 × Number of kilograms = Approximate U. S. Gallons.

BUSINESS LAW IN DAILY USE

The following brief statements pertaining to business law comprise the essence of many pages of legal reading:

1. Ignorance of the law is no excuse.
2. Principals are responsible for the acts of their agents.
3. Checks or drafts must be presented for payment without undue delay.
4. The law compels no one to do impossibilities.
5. Signatures made with lead-pencil are good in law.
6. Contracts made on Sunday are not enforceable.
7. A receipt for money is not conclusive.
8. The acts of one partner bind the other partners.
9. The word "limited," in connection with a firm name, indicates that the responsibility of each of the firm members is fixed.
10. An agreement without valuable consideration is void.
11. It is a fraud to conceal a fraud.

CONTRACTS

CONTRACTS.—A contract is an agreement, that is enforceable at law. It is made between two or more persons, and by this agreement rights are acquired by one or more of the parties to acts or forbearances, on the part of the other party or parties.

There are five elements that are required to make up a contract:

1. Offer and acceptance.
2. Seal or consideration.
3. Capacity of parties.
4. Reality of consent.
5. Legality of object or intention, and in some contracts there is a sixth element:
6. Special formality.

These six elements are briefly discussed as follows:

1. Offer and Acceptance

(*a.*) A quotation of prices, or a price list issued by a firm, is usually only an invitation to buy, and is not a legal offer to sell the goods mentioned. Unless the buyer's order is accepted by the seller, there is no contract.

(*b.*) The statement that "All quotations are subject to price changes without notice," is a protection against lawsuits.

NOTE. If the dealing be by correspondence, it will be well to bear in mind the general rule, that an offer becomes effective from the date of its reception by the offeree, while an acceptance becomes effective upon the date of posting. The acceptance must be unconditional else it will simply be a counter-offer. If the offer be by letter and the offeree accepts by telegram, the acceptance is not effective until receipt by the offerer.

2. Seal or Consideration

(*a.*) A seal may consist of a piece of wax, colored wafer, a scroll seal, a shaped paper wafer with the word "seal" printed on it, and in some states a drawing to represent a seal is sufficient. Sometimes the letters "L. S." are used.

(*b.*) Consideration is something of value, given by one party to the other, for whatever he is to get by the contract terms.

(*c.*) Usually either seal or consideration is sufficient, without both being required.

3. Capacity of Parties

(*a.*) There are five classes of parties who are limited, as to capacity of becoming parties to a contract, as compared to ordinary parties:

1. Mentally deficient parties.
2. Married women.
3. Minors.
4. Corporations.
5. Foreigners.

4. Reality of Consent

In order to make an agreement contain reality of consent, there *must not have been:*

1. Fraud.
2. Force.
3. Misrepresentation.
4. Undue influence.
5. Mistake or misunderstanding.

5. Legality of Object

(*a.*) A contract is not proper, if it violates the Constitution, the statute laws of the country, or of the state in which the parties are subject, or violates national treaties, or injures the public as a body, etc.

(*b.*) The courts will usually enforce an agreement entered into on Sunday, if the agreement has been recognized as binding by the parties on a weekday.

NOTE. Contracts operating for total restraint of trade are forbidden on grounds of unfair competition. Section 3 of the Federal Clayton Act prohibits "Tying Clauses" in contracts, which tend to substantially lessen competition, or to create a monopoly. A "Tying Clause" is one that provides that an article be sold only on condition that users thereof will deal exclusively with the same seller in the purchase of other articles. On May 25, 1917, the Trade Commission made its first affirmative decision determining that a contract for the sale of mimeograph machines, which contained a provision that all supplies used in connection with the machines were to be purchased from the manufacturers, involving more than 79 per cent. of the commerce in stencil duplicating paper, constituted sufficient tendency toward a monopoly to violate this law.

(*c.*) A retailer's agreement not to cut price on a patented article is usually upheld, although refusal of a manufacturer to sell again to a retailer who breaks such an agreement or to blacklist him, is subject to suit.

6. Special Formalities.

This element of a contract is only required in special contracts, such as suretyship, real estate, and some others.

After signing a contract, never alter it unless all parties to the contract *consent.* This should be noted on the contract at the altered point.

SALES

SALES.—Generally a buyer who sees what he is buying cannot later return the purchase because he finds it to be of inferior grade. The buyer must judge for himself the value of the goods and must not be misled by the praise of the seller.

If a buyer depends upon the truthfulness of the seller's representations, as to the quality of the goods, he should secure a written warrant of the seller's representations.

When a sale of goods is made from a sample, the sample must be an honest one and correspond in grade and quality to the bulk of the goods.

The seller may freely state his opinions, regarding the merits and qualities of the goods offered for sale, but he must not misrepresent facts, with the intention of deceiving the buyer, or the sale will be void.

BUYING AND SELLING TERMS

"**F. O. B. Destination**" is a term, meaning that the seller is to furnish the material, pay the freight and take all risks until the material reaches the point of delivery agreed upon.

"**F. O. B. Steamer**" is a term, holding the seller to deliver the material involved aboard a steamer, in proper shipping condition, after which all risks and expense are to the account of the buyer.

"**F. A. S. Steamer**" is a term, interpreted to mean that the seller must deliver the material involved alongside of the steamer, on a lighter, or upon the receiving pier of the steamship. The material must be in proper shipping condition. All further risks and expense are to the buyer's account.

"**C. I. F.,**" which is interpreted as Cost, Insurance and Freight, holds the seller to furnish the goods, pay the freight, and the insurance up to the point of delivery. All other risks, while material is in transit are for the account of the buyer. The carrier is the buyer's agent.

"**C. F. or C. A. F.,**" is interpreted as meaning that the seller furnishes the goods and pays the freight to the point of delivery as agreed upon. The seller pays no other expenses. Risks while the material is in transit are for the buyer's account.

In the case of "**F. O. B. shipping point**" contracts of sale, it is understood that the goods are to be "delivered free on board" the shipping point. The seller must pack the goods properly, put them on board, address them, secure shipping papers, and forward these papers to the buyer, so that he may secure the goods on arrival. The carriers are the buyer's agent. For this reason, all disputes coming up after clean documents have been received from the carrier by the seller must be settled between the buyer and the carrier. In the case of sales contracts based upon F. O. B. shipping point, with "cash or payment against documents," the seller may take out the shipping papers in his own name, thus preserving a lien on the goods for payment. Sales made on the basis of "F. O. B. Destination" involve that the seller pays the freight, retains title to the goods, assumes the risk, or loss or damage, until the destination named has been reached. Delivery can then be made to the buyer while the goods are still in the hands of the carrier, providing they are in good condition, thus constituting a good delivery. If the goods reach the destination in a damaged condition so that good delivery cannot be made, the seller must stand the loss.

It must be understood that the term F. O. B. (Free on Board) means that the material must be placed on some vehicle that will take the shipment to the buyer.

In the case of sales based upon C. I. F. (Cost, Insurance and Freight) the carrier is the buyer's agent. The delivery point is the shipping point. The seller takes out insurance and sends it to the buyer. The delivery is made at the warehouse or other point at which the goods may be when sold. The buyer stands the charges for taking the goods from this destination to the railroad or steamship. He stands all charges not included in the cost of the goods themselves, the cost of the insurance, and the cost of their carriage. The seller pays for the carrier's charges and the insurance during transportation. In all cases the destination of the goods should be named in the contract, for the seller's protection.

PROMISSORY NOTES

The "maker" of a note signs it.

The "payee" receives payment for it.

The "holder" has possession of it.

The "indorser" writes his name on the back of it and becomes responsible for the payment of it.

Notes are negotiable or transferable, when they contain the words, "or bearer," but no transfer of the latter can be made without the endorsement of the payee.

The words "Without Interest," under the note, means interest bearing after maturity.

The words "With Interest," under the note, means interest bearing from date.

The words "Value Received" are proof that the note represents actual value.

The "Day of Maturity" of a note is the day it becomes due.

In cases where the rate of interest is not specified, the legal rate of interest will apply.

In many states, the time of payment is postponed three days, called "days of grace."

A "Protest" is a notice sent to the indorser, that the maker of a note has failed to pay it. The protest to be valid must not be sent earlier than the last day of grace.

A note signed by two or three or more persons, who thus become jointly and severally responsible for the note, is called a "Joint Note."

WOOD BARRELS

BARREL MANUFACTURE.—The most desirable wood for use for tight cooperage is white oak. It is very heavy, hard, strong, tough and of coarse texture. It is only porous enough to allow sap to penetrate. Wood that is grown in mountain districts having a lime formation produces the best quality staves and heading, practically free from worms. It has been found that worms are likely to attack trees that have been exposed to fire, or have had their limbs broken.

The process of making staves can be divided for illustrative purposes into five branches or steps: (*a*) Tree felling, (*b*) Blocking, (*c*) Bolting, (*d*) Stave sawing, and (*e*) Seasoning. The only part of the tree that is used for making staves and heading is that part below the first or lowest branches, as no knots can be allowed in the finished product.

Heading is made 7/8ths of an inch thick. Staves are cut 13/16ths inch thick, so that after they are dried they will be an even 3/4ths inch. They are 34 inches long and are purchased on a 4 1/2 inch basis.

The staves are kiln dried. In this process they are first passed into moist heat and sweated to draw the moisture from the inside to the outside of the timber. Oak usually contains about 3 per cent. actual moisture. The moisture is then dried off by varying degrees of heat. The staves should never be made bone dry, as that would cause cracking and loss of strength. However, not enough moisture should be left in the wood to permit the barrel shrinking after it is finished. A jointer is next used to give the edges of the staves a true, smooth finish.

The staves are next passed to the "raisers" or "setters-up," and are piled in a circle and held in place by a truss or heavy iron hoop. This is now called a "shook," or uncompleted barrel. The barrel shook is next placed in a steam room, where it is saturated with steam, causing the wood to become pliable. The staves can then be drawn together, and are then held in place by another truss. The barrel is then dried and the staves have a permanent set. The barrel is next leveled and the truss hoops are drawn tight by a pulling machine. The bung hole is cut. The ends of the staves are prepared for holding the heads by the "croizing machine." The heads are put in and the hoops are drawn tight. In order to test the barrel for worm holes it is given a first inside coat of glue. After this the second coat of glue is applied and the barrel is painted.

GLUING.—Hide glue is used, as it has been found to be better for this purpose than bone glue. The gluing operation consists in putting enough glue into the barrel to size it, and then the barrel is turned up on each head and shaken, to spread the glue.

Glue should be soaked over night in cold water, using just enough water to cover it. In the morning the glue will have become soft and will melt and dissolve readily when put into the glue kettle. Glue should be kept at a uniform temperature, and it is recommended that a thermometer be kept in the glue pot. The glue should never be boiled, because it will be spoiled. The glue kettle should be kept clean and no glue be allowed to remain in the kettle. Each day's gluing should be started with fresh, sweet glue. Always wash out the glue troughs when the gluing is done with hot water.

PAINTING.—The barrels are painted in a special machine. The machine has two disks, which are brought up against the barrels' heads and revolve, thus spinning the barrel. The paint is then squirted on the barrel from several outlets under the barrel and the spinning spreads the paint. Brushes are provided to wipe off the excess paint. The heads are painted by hand.

When painting barrels, clean off the sides and heads; the sides can be cleaned with a stiff brush and the heads can be washed with kerosene. Never paint over dirt or paper labels, they should be removed with a scraper and hot water.

Barrels should be painted the same day they are glued. All barrels should be painted with the bung in them, to avoid paint getting inside. Do not cross colors, that is paint red barrels blue or *vice versa*. Sort the barrels, and give those requiring the most paint the first coat, then thin down the paint to the proper consistency for the barrels that do not require as much.

BUNGS.—The bung should always be driven to have the grain of the bung parallel to the grain of the bung stave. A bung driven cross grain encounters resistance and may split the stave.

WOOD BARREL NOTES

GENERAL.—It is necessary in using wood barrels to provide a different grade barrel for each kind of oil to be handled. Refined oils require a better grade of barrel than fuel oils, for example: In transporting gasoline and naphthas in wood barrels, it is necessary to use a specially prepared barrel, made to conform to Interstate Commerce Commission specifications No. 9, which barrel is generally known as the I. C. C. Barrel. Wood barrels are entirely used for carrying greases, owing to the difficulty of removing this material from a steel barrel. Different grades of wood barrels are used for shipping asphaltic products according to their consistency. The wood barrel is used for export shipment, owing to lower original cost of this style package and the excessive cost of returning a steel package.

BARREL NOTES.—"Loose Hoops" may be caused by making the staves of timber not sufficiently dried, and the resulting shrinkage causes the hoops to loosen.

SLACK HEADS cannot usually be detected, unless the chime hoop is removed first and the bevel examined. The head is made with a short bevel on top and a long bevel on the bottom. The long bevel must be drawn tight into the groove in the staves, so that the edge of the head will butt against the bottom of the groove.

FILLING of oil barrels should not be done until at least three days after gluing. If the filling is done too quickly, the barrel will probably leak. The glue must be entirely dried. Often the glue appears to be dried, but is only really dry on the surface, and below this surface the glue is still soft. If a barrel in this condition is used and after filling is put in a warm place, such as in the sun, the glue will run so that pockets, which may cause the barrel to leak, will be formed. This may also cause the glue to run out mixed with oil. Glued barrels should be kept in storage at least seventy-two hours, to permit the glue to set before filling.

CLOUDED AND LIVERED OIL.—This condition may be due to a small amount of alkalie remaining in the oil, and if there is moisture present, the oil will quickly take up a lot of glue. This condition particularly occurs with paraffin oils or other treated oils.

REAMING.—When the barrels are reamed, sawdust and chips will fall into the barrel, causing trouble when the oil is used. This is often the start of sediment in the oil. Great care should be taken to remove the dust, etc.

BARREL STORAGE.—Wood barrels should always be stored in the warehouse, resting on the bilge, never on the ends. Concrete floors are very hard on wooden barrels. In this case particularly, the barrels should be stored on skids. Two-by-three-inch skids laid about fifteen inches apart provide the best form of storage. Thus the barrels are supported at their strongest points; that is, about seven or eight inches from the bung. Spruce or any similar wood is satisfactory for skid material. If the barrels are exposed to moisture and then glued before the wood is thoroughly dried, the barrel will probably "mold." "Mold Hairs," or whiskers, will appear on the inside of the barrel, and this mold will cloud the oil and also cause it to have a very disagreeable odor, due to the decomposition of the glue, caused by the moisture coming out of the wood under the glue coating. This chiefly occurs in old barrels that are re-glued. Sediment appearing in the oil can often be traced to this cause.

The outside district oil storage house should be provided with the following named tools for keeping the barrel in good condition:

(*a*) One four-pound cooper's hammer.

(*b*) A bung pick.

(*c*) A Nantucket driver.

A supply of extra bungs should be kept on hand.

WOOD BARRELS: DIMENSIONS.—A regular oil barrel measures about 13.30 cubic feet. Steamship companies usually figure 12 cubic feet per barrel.

A half-barrel measures about 7.9 cubic feet. Steamship companies usually figure these at 8 cubic feet.

A wood barrel usually weighs about 68 to 75 pounds. A half barrel usually weighs about 50 pounds.

STANDARD WOODEN BARREL SPECIFICATIONS

STANDARD WOODEN BARREL SPECIFICATIONS.—It is claimed that for all but the most penetrative liquids a red oak barrel, when properly glued, will give practically as good service as a white oak barrel. A committee of prominent coopers have worked out the following standardized packages:

The average wooden barrel weighs when new about 68 pounds and when old about 71 pounds.

STANDARD WOODEN BARREL SPECIFICATIONS

Number	Size	Wood	Hoops	Bung	Coating	Use
1	50–52 gals.	¾" White Oak, tight sap	Six—17 and 18 gauge	2" Bilge	Glue or silicate test	Special and difficult work, alcohol and spirits.
2	50–52 gals.	¾" White and Chestnut Oak	Same	Same	Same	I. C. C.—10 specification. For inflammable oils with flash point above 20 degrees F. Shellac, varnish, Japan, leather dressing.
3	50–52 gals.	Same with 1" heads	Six—16, 17, 18 gauge	Same	Same	I. C. C.—9 specification. Inflammable oils flash point below 20 F. viz:—Naptha, gasoline, ether, rubber cement, benzine.
4	50–52 gals.	¾" White and Chestnut Oak	Six—18 and 19 gauge	Same	Same	Common oil barrel. Light lubricating oils, road oils, linseed oil, etc.
5	50–52 gals.	¾" White and Chestnut Oak. Selected sound sap stock	Same	Same	Same	For thin or penetrating oils such as: Turpentine, burning oils, dryers, cottonseed oil, dryers. (Cotton seed always in silicated barrels.)
6	50–52 gals.	¾" Red Oak	Six—17 and 18 gauge	Same	Same	I. C. C.—10 specification. Paints, heavy varnishes and oil products having flash point above 20 degrees Fahr.
7	50–52 gals.	Same	Six—18 and 19 gauge	Same	Same	Common oil barrel, heavy lubricating oil, black oil, etc.
8	55–60 gals.	¾"	Six—18 and 19 gauge	Same	Same	Common grease or glucose barrel—oil soap, grease and oils that pour thick.

NOTE.—When eight (8) hoops or finished coating is desired it should be mentioned in connection with above numbers. For other sizes, merely specify size and number: Example: 32 gal. No. 3. Most cooperage shops can supply the following standard sizes: 5, 10, 15, 20, 25, 32, 40, 45, 52, 55, 60 gallon. Use a standard size when possible. The average wooden barrel weighs when new about 68 pounds, and when old about 71 pounds.

GAUGING AND SAMPLING

VOLUME OF BARREL CONTENTS BY GAUGE AND WANTAGE RODS.—The "gauge rod" measures the distance from the center of the bung hole to a point on the "crow." The "crow" is the point of union of the head and staves.

The average of two measurements taken in both directions is used. A slide is provided on the rod to assist the determination of the center of the bung and for registering the reading. The "Cut Gauge" is the average reading and equals the volume of the barrel.

A "Wantage Rod" is used to determine "outage." "Outage" is the difference between the full capacity and the actual contents of the barrel.

The use of the "gauge rod" is being discontinued owing to many objections, such as foaming of the oil, which makes the reading of the gauge inaccurate, temperature effect on volume, etc.

When gauging a barrel, if the bung stave is too thick, the gauge capacity will be too small, if too thin it will be too large.

(From proposed Rules of Independent Oil Men's Association Governing Trade.)

Barrels and other small containers—All containers unless otherwise specified shall be gauged and sampled as follows:

For all containers not otherwise provided for herein, take the actual weight in pounds avoirdupois of the empty container and also of container when filled, computing the contents into gallons by dividing the net weight by the weight per gallon at 60° F. as shown from the gravity of the oil in the following table:

For wood barrels a gauge rod, when specified, may be used. The rod shall be either of steel or of a good quality of hard wood, not liable to shrinkage, expansion, or warpage, under ordinary conditions. If made of wood the lower end of the rod should be protected by a metal tip to prevent any wearing which would alter the indications of the scale. The over-all length of these rods should be approximately 38 inches. The tips of the rod should be beveled on two sides so that the same will fit closely into the corner of the angle formed by the head of the barrel and the staves. Two opposite sides of the rod should be graduated in inches and fractions thereof, another side of the rod graduated in gallons up to 120 gallons.

The rod should be equipped with a metal slide with arms extending from same which may be drawn up snugly against the inside of the staves in the center of the bunghole and so constructed that it will give indications on the scaling on the rod showing the angular distance from the point where the head of the barrel and the staves meet on the side directly opposite the bung, to the center of the bunghole on the inside of the staves.

In gauging a barrel this dimension should be taken from the center of the bunghole to the opposite side of the end of the barrel, at both ends, and the average of the two readings considered the capacity of the barrel.

A tare of one gallon on barrels and one-half gallon on half barrels should be deducted therefrom; barrels should be filled to within two inches of inside of top stave.

To sample a tank car take a quart from the bottom, a quart from the middle, and one from the top of the contents of the car and mix thoroughly.

To sample a smaller container stir or roll (if it is a barrel) thoroughly and draw off a quart.

OLD WOODEN BARRELS

PREPARATION OF OLD BARRELS.—The large refineries are equipped to receive old barrels and to clean and prepare them for use again. This is an important end of the business, and a brief description is therefore given:

CLEANING.—The barrel is first steamed to loosen any foreign matter, and is washed with soda water and a scrubbing machine. It is next rinsed with fresh water and dried over hot air jets.

REPAIRING.—Dished or buckled heads are straightened by steaming. Damaged and broken heads, staves and hoops are replaced by new ones. Open joints are flagged or caulked. After scrubbing the barrel should be thoroughly dried before gluing. The hoops are next driven by a machine and the barrel is glued.

NOTES.—When old barrels are received at the warehouse they should be piled with their bungs down for at least two weeks, to insure that they are perfectly drained. They should then be carefully inspected, to make sure that they contain no dampness or oil. If they still contain oil, they should be steamed and washed out with hot water. After steaming and washing with hot water, they should be left to drain with bungholes down, and not used until perfectly dry. They should never be glued, if they contain decomposed glue, oil, water, or are damp.

When coopering, the head-hoops should never be driven below the end of the staves. Considerable trouble will be eliminated by removing old taps and plugs and replacing them with new ones. Burlap or bung cloth should be avoided in putting in the bungs.

STEEL BARRELS

GENERAL.—Some of the largest oil companies are rapidly replacing the wooden barrel with the steel barrel, in order to relieve the expense of recoopering the wooden barrels on return and to reduce leakage to a minimum. There are several advantages to the consumer receiving oil in steel barrels, namely, the reduced fire risk, the lower price of the oil in this form of container, the absence of leakage and the convenience of handling.

APPROXIMATE WEIGHTS OF STEEL BARRELS, FILLED WITH OIL OF VARIOUS INDICATED GRAVITIES

Weights based on Defiance "Extra" Steel Barrels 55 gallon capacity and filled one gallon out. For Defiance "Special" Steel Barrels add 15 pounds.

Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel	Gravity Baume	R. R. Weight per Barrel
16	505	26	475	36	450	46	430	56	410	66	395	76	380
17	500	27	475	37	450	47	430	57	410	67	390	77	375
18	500	28	470	38	445	48	425	58	405	68	390	78	375
19	495	29	470	39	445	49	425	59	405	69	390	79	375
20	495	30	465	40	445	50	425	60	405	70	385	80	370
21	490	31	465	41	440	51	420	61	400	71	385	81	370
22	485	32	460	42	440	52	420	62	400	72	385	82	370
23	485	33	460	43	435	53	415	63	400	73	380	83	370
24	480	34	455	44	435	54	415	64	395	74	380	84	365
25	480	35	455	45	430	55	415	65	395	75	380	85	385

THE AVERAGE DIMENSIONS OF A TYPICAL STEEL BARREL.—The dimensions of the G*E*M Steel Bilged Barrel, made by the Pressed Steel Products Company, are as follows:

Capacity	55 gallons
Diameter at bilge	24 inches
Length in inches	35 inches
Weight	100 pounds

STEEL BARREL NOTES

VOLUME OF BARRELS:

$V = D^2 \times L \times 0.0034$ Where V = volume of barrel in gallons.
D = mean diameter of barrel in inches.
L = length in inches.

(Mean diameter equals 1/2 the sum of the head and bung diameters.)

CANS AND CASES

TIN

TIN. "COKE TIN PLATES."—The base of these plates is the best grade of soft steel. The word "Coke" is used in the trade to indicate finish. The trade retained it from the time when high-grade tin plates were made from Charcoal Iron and the lower grades from Coke Iron. From this origin, plates with lighter coating of tin are called "Coke Tin Plates."

The grades furnished by The American Sheet and Tin Plate Company are as follows:

	Markings		
American Cokes	90 lbs.	20″ x 28″	
American Best Cokes	95 lbs.	20″ x 28″	
American Cokes, Extra Clean	100 lbs.	20″ x 28″	Extra Clean.
Kanners Special Cokes	I. C.	20″ x 28″	K. S.
American Stove Board Cokes	I. C.	20″ x 28″	U./A.

Tin plates are generally packed in boxes, and the unit of value and measurement is known as the "base box." A base box is 112 sheets of 14 by 20 inches, or 31360 square inches of any size.

TIN. "CHARCOAL TIN PLATES."—Many specifications for cans call for charcoal tin plates instead of coke tin plates. The base metal of these plates is prepared with the view of securing a fine gloss and working quality. The American Sheet and Tin Plate Company designate the amount of coating and finish by letters A to 5A. A has the least amount of coating and each A indicates an additional quantity.

The grades furnished by the American Sheet and Tin Plate Company are as follows:

	Markings		
American 1A Charcoals	I. C.	20″ x 28″	1A
American 2A Charcoals	I. C.	20″ x 28″	2A
American 3A Charcoals	IX	20″ x 28″	3A
American 4A Charcoals	IXX	20″ x 28″	4A
American 5A Charcoals	IXXX	20″ x 28″	5A
American Premier Charcoals	IXXXX	20″ x 28″	Premier

TIN. TAGGERS TIN.—This designation is usually applied to either Coke or Charcoal Plates, 65 pound basis (36 gauge or lighter), according to the American Sheet and Tin Plate Company.

WEIGHTS AND GAUGES OF TIN PLATES

Approximate Gauge	Weight per Base Box
No. 38	55 lbs.
No. 35	70 lbs.
No. 31	90 lbs.
No. 30 1/2	100 lbs.
No. 30 I. C.	107 lbs.
No. 28 I. X.	135 lbs.
No. 28 I. X. L.	128 lbs.

WEIGHTS AND DIMENSIONS FOR CANS AND CASES

Three-Eighths-Inch Case

One case containing two five-gallon cans:
3/8-inch Case. (Regular Export Case.)

Thickness of sides, tops and bottoms	3/8"
Thickness of ends	3/4"

Measurements: 10 3/8" x 20 1/2" x 14 3/4".
Tare Weight: 16 1/2 pounds. (Case containing two cans.)
The case measures: 1.815 cubic feet.

Five-Eighths-Inch Case

One case containing two five-gallon cans.
5/8-inch case. (Heavy Case.)

Thickness of sides, tops and bottoms	5/8"
Thickness of ends	3/4"

Measurements: 10 7/8" x 20 3/4" x 15 3/8".
Tare Weight: 22 pounds. (Case containing two cans.)
The case measures: 2.008 cubic feet.
(Steamship companies would figure the cubical measurements as: 11 x 12 x 15 equal 2.01 cubic feet.)

Seven-Eighths-Inch Case

One case containing two five-gallon cans.
7/8-inch case. (Extra Heavy Case.)

Thickness of sides, tops and bottoms	7/8"
Thickness of ends	1"

Measurements: 11 3/8" x 20 3/4" x 15 3/4".
Tare Weight: 29 pounds. (Case and two cans.)
Cubic Measurement: 2.1513 cubic feet.
(Steamship companies would figure: 11 x 21 x 16 equal 2.14 cubic feet.)

Shipping Weights of Greases in Cans and Cases

One case (1–50-pound tin)	61 pounds per case
One case (1–25-pound tin)	32 pounds per case
One case (1–10-pound tin)	14 pounds per case

NOTES ON CANS AND CASES.—The usual commercial can for shipping oil is made with a capacity of 5 1/8 U. S. gallons. These cans are packed two to a case for shipment.

Cans are usually made from 107 I. C. tin. A regular can made of I. C. 107 tin weighs 2 pounds 7 ounces, and one made from I. X. 135 tin weighs 2 pounds 12 ounces.

NAVY DEPARTMENT SPECIFICATIONS (CANS AND CASES)

FIVE-GALLON TIN CANS

GENERAL.

1. To be made of high-grade material of good workmanship and be free from any defects which may affect the serviceability of the can.

MATERIAL.

2. To be made of I. C. 107 pounds prime coke tin plate. If required, the contractor should furnish a certificate to the effect that the tin plate used is of the grade specified.

CONSTRUCTION.

3. To be as follows.

(*a*) Shape and size: To be of square shape with rounded corners. Body to be 9 3/8 inches square at top and bottom and 13 3/4 inches total height.

(*b*) The ends of the body to be either double-seamed or crimped on the body; if double-seamed, the body shall be flanged; if crimped, the body shall be hemmed.

(*c*) Soldering: All seams to be well soldered, the solder being caused to flow between the two metals constituting the seam in such a manner as to produce a thoroughly substantial union between metals.

(*d*) Handle and filling cap: Can shall have a handle made of No. 9 galvanized coated wire, held by a tin clip soldered to the top and a 1 1/4-inch screw cap near one corner. Cap to be packed with an inner disk of cork, linoleum, or paraffin-coated cardboard to prevent leakage when screwed tight; to be provided when specified with inner seal of tin or some equally tight closure approved by the department.

CAPACITY.

4. The capacity of the can to be not less than 5 1/8 gallons (U. S.).

TESTS.

5. The can when submerged in hot water shall withstand without leakage an air-pressure test of five (5) pounds.

Cases are generally made of yellow pine. The usual commercial package has 1/2-inch sides and 3/4-inch ends. The ends are often made of several pieces, which are held together by gluing, tongues, or by a special form of tack.

The specifications for U. S. Navy cases is given as follows:

CASES FOR FIVE-GALLON TIN CANS

GENERAL.

1. To be made of high-grade material, of good workmanship, and be free from any defects which may affect the serviceability of the case.

MATERIAL.

2. To be as follows:

(*a*) *Lumber.*—Cases to be made of new, dry, well-seasoned, sound white pine or any wood of equal or superior strength having no loose

knots or knots liable to get loose in any part. Sides, top, and bottom to be made of 1/2-inch and ends of 3/4-inch material.

(*b*) *Nails.*—Six-penny nails shall be used for securing top, sides, and bottom to ends and four-penny nails for securing top and bottom to sides. Screws of equal efficiency may be used in place of nails.

CONSTRUCTION.

3. To be made of such size as to hold, snugly fitting, two five-gallon cans, each 9 3/8 inches square at the top and bottom and 14 1/2 inches high. The ends of case to be made of one-piece material or be tongue and grooved and glued; other types of joints may be used which have been approved by the Bureau of Explosives. All nails securing top, sides, and bottom to ends to be spaced not more than 2 1/2 inches. All nails securing top and bottom to sides to be spaced not more than 8 inches.

MARKING OF BOXES.

4. Each box shall be plainly marked with the words: "Complies with I. C. C. Spec'n No. 2"; or, if desired, this marking may be indicated by a symbol consisting of a rectangle as follows:

I. C. C.—2.

The letters and figure in above symbol shall be at least 1/2-inch high. The symbol shall be understood to certify that the case complies with all the requirements of Specification No. 2 of the Interstate Commerce Commission.

TANK CARS*

TANK CAR NOTES.—(*a*) The cover of tank car should be sealed, the seal showing a number, which shall also be shown on invoice.

(*b*) The tank car should be examined for leakage at valve and seams and condition noted on expense bill as provided.

(*c*) The temperature of the contents should be taken at bottom, centre and top of contents and the average determined.

(*d*) Should the tank car show an outage, measure same from the bottom of the dome on each end to the surface of the oil, adding same together and dividing to determine outage from exact centre of dome. Should the contents be even to the bottom of dome at a temperature above normal, 60° F., deductions should be made based on the average temperature at a rate of 1 per cent. for every 20° F. Should contents be even to the bottom of dome at a temperature below normal, 60° F., average should be based on the average temperature.

TANK CAR OUTAGE TABLE†

Calculated from 1/4 Inch to 5 Inches Out of Shell, at 60 Deg. Fahr. Capacity of Car in Gallons at 60 Deg. Fahr.

	4231	6000	6641	7000	8087	8102	8505	10000
1/4	3	4	4	4	5	5	5	6
1/2	6	8	8	8	10	10	10	12
3/4	9	13	13	13	16	16	17	19
1	13	18	18	18	23	23	25	26
1 1/4	18	24	25	25	31	31	33	36
1 1/2	23	31	33	33	39	39	45	46
1 3/4	29	38	41	41	48	48	56	58
2	35	46	49	50	58	58	67	71
2 1/4	41	54	58	59	69	69	79	84
2 1/2	48	63	68	69	80	80	92	98
2 3/4	55	72	78	79	91	91	105	111
3	63	82	88	90	103	103	119	125
3 1/4	71	92	99	101	115	115	133	140
3 1/2	79	103	110	113	128	128	148	156
3 3/4	87	114	123	125	141	141	163	171
4	96	125	134	137	154	154	178	186
4 1/4	105	136	146	150	167	167	194	203
4 1/2	114	148	159	163	181	181	211	220
4 3/4	123	160	172	176	195	195	228	237
5	133	173	186	190	210	210	244	254

* From Proposed Rules of I. O. M. A. Governing Trades.
† From I. O. M. A.

UNLOADING TANK CARS.—On arrival of car, the following instructions for unloading should be carefully observed:

Break dome seal and unscrew dome cover by placing bar between dome cover lugs and knob. Do not hammer the dome cover.

When dome cover has been removed, gauge contents of car and examine contents carefully by taking sample. If there is any shortage of contents or if for any reason whatever contents are not acceptable, before unloading the car, notify shipper by telegraph or telephone, giving full particulars, as generally no allowances of any nature will be made after car has been either partially or fully unloaded.

If contents of car are satisfactory and ready for unloading, move valve rod handle in dome back and forth a few times to see that valve is properly seated. If valve is tight, open stop cock slowly, having a pail to catch any oil that may be in outlet tube. Then attach unloading connection to stop cock and raise valve by use of valve rod handle in dome.

If valve becomes detached from valve rod, it can be recovered and connected by using a wire rod bent at right angles on one end and feeling for the hole in the valve where the valve rod pin goes through.

Place dome cover over opening, resting same on bar extending across dome opening to allow air to enter car. Do not replace dome cover while unloading as this will result in collapse of tank.

After car is unloaded shut stop cock, replace dome cover, and remove all shipping cards from car. Inflammable placards and railroad defect cards must not be removed.

WHEN HEATING COILS ARE USED.—Attach a globe valve to coil outlet, leaving same wide open. Connect steam line to inlet of coil and after steam shows at outlet, adjust valve so as to take care of condensation.

After unloading blow out heating coil to remove all condensed steam.

BUYING AND SELLING OILS BY WEIGHT

ADVANTAGES OF CHECKING OIL GALLONAGE BY WEIGHT.—(*a*) All measurements can be referred to a standard volume, at 60° Fahr.

(*b*) Less liability of personal error.

(*c*) Quicker than checking by gallonage method.

(*d*) Can be made very accurate and yet be made rapidly.

(*e*) Assurance that the gallonage obtained is correct, regardless as to whether the oil has been expanded by heat or contracted by cold.

METHOD OF OPERATION.—(*a*) Take the gross weight of the Barrel and Oil combined.

(*b*) Empty the barrel and allow it to thoroughly drain.

(*c*) Take Gravity and Temperature of the oil, with a Hydrometer and Thermometer.

(*d*) Weigh the empty barrel (Tare weight).

(*e*) Refer to Gravity-Weight Table (see Index) and select the corresponding weight per gallon, as indicated by the gravity reading, when corrected for the number of degrees above or below 60° Fahr. (See temperature correction table, under Gravity.)

If $W_1 =$ Weight of the Barrel and Oil.

$W_2 =$ Weight of the Barrel when *drained* empty.

$W_3 =$ Weight of the Oil.

$B =$ Weight of one gallon of the Oil at the corrected gravity.

Then: $W_1 - W_2 = W_3$.

$\frac{W_3}{B} =$ Correct Gallonage of the Oil.

MARKETING QUOTATION NOTES

SELLING PRICE COMPUTATION.

For the use of those who are engaged in determining a selling price for an oil, after the base price in bulk at the plant is determined, the following form will be of value. This form should be attached to the filed correspondence, so that it will be readily obtainable, in case any question comes up as to how the quoted price was arrived at.

Town________________________

PRODUCT

WOOD BARRELS		STEEL BARRELS	
Bulk		Bulk	
Profit		Profit	
Cost of Bbl.		Use of Bbl.	
Filling and Handling		Filling and Handling	
Hauling		Hauling	
Freight per gal. in pkg.		Freight per gal. in pkg.	
		Return of Empty	
TOTAL		TOTAL	

CANS AND CASES		TANK CARS	
Bulk		Bulk	
Profit		Profit	
Cost of Can and Case		Car Service	
Hauling		Freight per gal.	
Handling			
Freight per gal. in pkg.			
TOTAL		TOTAL	

QUOTATION RECORDS.—The form shown below is used by a large oil company for keeping a record of quotations made, so as to know at all times their open commitments. A copy of the sheet is sent to the customer quoted, and a copy is fixed in a loose-leaf binder, where it stays

until the time of the offer has expired, or has been accepted. Thus all offers are in compact form, so that there is no danger of overselling, and at the same time the terms are in plain, concise form, in both the hands of the customer and the oil company.

To J. B. Doe Company,
10 14th Street,
Philadelphia.

Date Jan. 2nd, 1919

Inquiry of Dec. 31st, 1918

Quotation No. L 199

We beg to offer subject to conditions set forth

Contract No..................

Grade	*Quantity*	*Price in bbls.*
#125 Oil	1 carload approx. 100 bbls.	22½c per gallon

Option Expires Jan. 4th, 1919
Delivery Prompt
Cost of Package Included
Freight f.o.b. Our Refinery, Oil City, Pa.
Terms 30 days net, no cash discount
Note

THE XTRA REFINING CO.
by J. B. Jones.

SPECIAL PROTECTIVE CLAUSE.—The following is effective protection:

"All quotations and contracts are made subject to payment by buyer (in addition to purchase price) of any internal revenue tax, war tax, duty, impost, tonnage, shipping or other charge, hereafter levied by any governmental authority on the product, the product container, transportation of product, the contract or agreement, or any matter connected therewith, unless buyer elects to waive delivery of the product, or this company elects to pay such tax. Deliveries shall not be required in case of partial or total interruption of transportation facilities, fires, strikes, interference of civil or military authority, or any cause beyond seller's control, or if because of war conditions, seller cannot deliver said product under normal freights, insurance and other costs."

TABLE FOR FINDING THE SELLING PRICE OF ANY ARTICLE

Cost to do business	Net per cent. profit desired																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30	35	40	50
15%	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	65	60	55	50	45	35
16%	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	64	59	54	49	44	34
17%	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	63	58	53	48	43	33
18%	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	62	57	52	47	42	32
19%	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	61	56	51	46	41	31
20%	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	60	55	50	45	40	30
21%	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	59	54	49	44	39	29
22%	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	58	53	48	43	38	28
23%	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	57	52	47	42	37	27
24%	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	56	51	46	41	36	26
25%	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	55	50	45	40	35	25

Rule: Divide the cost (invoice price with freight added) by the figure in the column of "Net Per Cent. Profit Desired" on the line with per cent. it costs you to do business.

Example: If a 6 ten-pound package of lubricating grease costs $2.20 and freight amounts to 40 cents, and it is desired to make a net profit of 10 per cent. on the basis that it costs 25 per cent. to do business, the table is used as follows:

(*a*) Select figure in table in column headed "10" and on line with 25 per cent. in "Cost to Do Business" table, which for the case assumed will be 65.

(*b*) 2.20
 .40
 ——
$2.60 cost.

65) 2.60 (4.00
 2.60
 ——

The selling price to give the desired percentage of net profit is $4.00.

TABLE FOR FIGURING NET PROFITS

IF YOUR COST OF DOING BUSINESS FIGURED ON SALES IS REPRESENTED BY ONE OF THESE FIGURES—

	%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%
And you mark your goods at one of these percentages above delivered cost	25	10	9	8	7	6	5	4	3	2	1	0	1 loss	2 loss	3 loss	4 loss	5 loss
	33 1/3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	40	18 4/7	17 4/7	16 4/7	15 4/7	14 4/7	13 4/7	12 4/7	11 4/7	10 4/7	9 4/7	8 4/7	7 4/7	6 4/7	5 4/7	4 4/7	3 4/7
	50	23 1/3	22 1/3	21 1/3	20 1/3	19 1/3	18 1/3	17 1/3	16 1/3	15 1/3	14 1/3	13 1/3	12 1/3	11 1/3	10 1/3	9 1/3	8 1/3
	60	27 1/2	26 1/2	25 1/2	24 1/2	23 1/2	22 1/2	21 1/2	20 1/2	19 1/2	18 1/2	17 1/2	16 1/2	15 1/2	14 1/2	13 1/2	12 1/2
	75	32 6/7	31 6/7	30 6/7	29 6/7	28 6/7	27 6/7	26 6/7	25 6/7	24 6/7	23 6/7	22 6/7	21 6/7	20 6/7	19 6/7	18 6/7	17 6/7
	100	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25

YOUR PERCENTAGE OF NET PROFIT IS REPRESENTED BY THE FIGURES AT THE JUNCTION OF THE TWO COLUMNS

Explanation: If your cost of doing business is 15 per cent. of your gross sales, and you mark a line at 25 per cent. above cost, your net profit is 5 per cent. on sales as shown in the diagram. If your cost of doing business is 18 per cent., and you mark a line at 60 per cent. above cost, your net profit is 19½ per cent. on sales.

SECTION 3

MECHANICAL ENGINEERING

WORK AND POWER

WORK is the product of force and space. The unit of work is the foot-pound. The foot-pound may be defined as the amount of work done, when a pound weight is raised through a distance of one foot, against the forces of gravity.

POWER.—Power is the rate of doing work.

HORSE-POWER.—Mechanical power is measured by horse-power. A horse-power is defined as being that rate of doing work, which would lift a pound weight 33,000 feet per minute, or 33,000 pounds one foot per minute.

BRITISH THERMAL UNIT.—A British Thermal Unit is a quantitative measure of heat, and is generally written as B. T. U. It is the quantity of heat required to raise the temperature of one pound of pure water one degree at 62° Fahr.; that is, from 62° to 63°. In the metric system, this unit is the "Calorie," and is the heat necessary to raise the temperature of one kilogram of pure water from 15° to 16° Centigrade. The heat values in B. T. U. are ordinarily given per pound and the heat values in calories per kilogram, in which case the B. T. U. per pound are approximately equivalent to 9/5 the calories per kilogram.. Investigators have determined that heat energy has a definite relation to work, one B. T. U. being equivalent to 777.52 foot-pounds, or approximately 778 foot-pounds.

To change English horse-power to B. T. U. per minute, use the following formula:

$$\text{B. T. U. per minute} = \frac{\text{Horsepower} \times 33000}{778}$$

$$\text{One horse-power} = \frac{33000}{778} = 42.4 \text{ B. T. U. per minute.}$$

CONVERSION FACTORS.—

Cheval-vapeur (Metric System) $\times$ 0.9863 = Horse-power.
Calorie $\times$ 0.252 = British Thermal Unit.
Kilowatts $\times$ 1.34 = Horse-power.
Watts $\div$ 746 = Horse-power.
Watts $\times$ .7373 = Foot-pounds per second.
1 calorie = 3.968 B. T. U.

TOTAL AVERAGE COST OF POWER PER BRAKE HORSE-POWER YEAR (308 DAYS)

(Taken from Lefax Data Sheets to the Nearest Dollar)

Size of plant	Cost of coal, per ton							
	$2.00		$3.00		$4.00		$5.00	
	Service		Service		Service		Service	
	10 hours	24 hours	10 hours	24 hours	10 hours	24 hours	10 hours	24 hours
100	$61	$96	$71	$116	$81	$136	$91	$156
200	53	83	62	101	71	119	80	137
300	46	74	55	90	63	107	71	123
400	42	67	50	83	58	99	66	115
500	37	59	44	73	51	87	58	101
600	32	51	38	64	44	76	50	88
700	28	45	34	56	39	67	45	78
800	25	40	30	50	35	59	40	69
900	23	36	27	44	31	52	35	61
1000	20	32	24	39	27	46	31	52
1500	18	28	21	34	24	39	27	45
2000	17	26	20	31	22	36	25	40
2500	16	24	18	29	21	33	23	37
3000	15	22	17	26	19	30	21	34
4000	14	21	16	24	18	28	20	31
5000	13	19	15	22	16	25	18	29

NOTE. In compiling this table, the following factors have been considered in totaling the average costs: Cost of attendance; cost of fuel; cost of oil, waste, etc.; fixed charges, including depreciation, repairs, interest, insurance.

APPROXIMATE COSTS OF STEAM ENGINES.—When estimating the "Cost of Producing Power" in any plant, it is necessary to know the approximate cost of the plant equipment, so that an "Interest Charge" and "Depreciation Allowance" may be added to the cost of fuel, labor, etc., to give the total cost of producing a "Horse-power Per Year" in that plant. The following figures give approximated costs of various engines, as follows:

Simple Slide Valve Engines .... $7.00–$10.00 per H. P.
Simple Corliss Engines .... $11.00–$13.00 per H. P.
Compound Slide Valve Engines ..... $12.00–$15.00 per H. P.
Compound Corliss Engines .... $18.00–$23.00 per H. P.
High Speed Slide Automatic Engines ... $10.00–$13.00 per H. P.
Low Speed Automatic Engines ...... $15.00–$17.00 per H. P.

COMPARATIVE FUEL COSTS OF DIFFERENT KINDS OF POWER. (BRUCE-MACBETH ENGINE COMPANY.)

(BASED ON THE OPERATION OF HUNDRED (100) HORSE-POWER ENGINE, OPERATING AT FULL LOAD)

Type of Engine	Fuel	Price of Fuel	Fuel per B. H. P. per Hour	Cost per B. H. P. per Hour	Cost per K. W. per Hour	Cost per *H. P. per Year	Cost per *K. W. per Year
Steam Engine Simple non-condensing	Bituminous Coal	$3.00 per ton	8 lbs.	$0.012	$0.019	$36.00	$57.00
Steam Engine Compound non-con.	Bituminous Coal	$3.00 per ton	5 lbs.	$0.0075	$0.0118	$22.50	$35.40
Steam Engine Compound-condensing	Bituminous Coal	$3.00 per ton	3 lbs.	$0.0045	$0.0071	$13.50	$21.30
Gas Engine	Natural Gas	$0.30 per M ft.	10 cu. ft.	$0.003	$0.0047	$9.00	$14.10
Producer Gas Engine	Anthracite Coal	$5.00 per ton	1 lb.	$0.0025	$0.0039	$7.50	$11.70
Producer Gas Engine	Coke	$3.00 per ton	1¼ lbs.	$0.0019	$0.003	$5.70	$9.00
Producer Gas Engine	Bituminous Coal	$3.00 per ton	1¼ lbs.	$0.0019	$0.003	$5.70	$9.00
Producer Gas Engine	Texas Lignite	$2.00 per ton	1¾ lbs.	$0.0018	$0.0027	$5.40	$8.10
Producer Gas Engine	Washington Lignite	$2.50 per ton	1½ lbs.	$0.0019	$0.0029	$5.70	$8.70
Producer Gas Engine	N. Dakota Lignite	$2.00 per ton	1¾ lbs.	$0.0018	$0.0027	$5.40	$8.10

* Operating at rated load for ten hours per day for 300 days.

HOW TO JUDGE THE ECONOMICAL VALUE OF EQUIPMENT

Work
- **Quality:** What kind of work will it produce?
- **Amount:** What is its maximum production?

Cost
- **Initial Cost.** How important a factor is the initial cost?
- **Economy:** Does it produce an economical result with a minimum wastage?
- **Labor Cost:** Does it decrease labor cost, by minimizing responsibility and attention, as well as increasing output?
- **Power Cost:** Is it economical in utilization of power compared with production?
- **Maintenance:** Is the maintenance economical; are adjustments easily understood and made; are repairs within easy reach?
- **Durability:** Is it well constructed? Is it up to date, and can improved devices be applied as it grows older? Is it standard?
- **Storage Space:** Is it compact? Can it be stored with a minimum of effort and economy of space?
- **Operation:** Is it complete? Does it only require a minimum of aid in producing, either mechanical or hand?
- **Total Cost:** Can the results obtained be summed up to produce a maximum economy?

Design
- **Flexibility.** Can it perform more than one type of work if necessity requires?
- **Adaptability:** Does it harmonize with existing working conditions, such as available power, rearrangement of space, etc., or does it require a changing around?
- **Practicability.** Is it practical from a mechanical standpoint?

Safety
- **Accident:** Is it designed and installed in such a manner as to minimize the chance of accident?
- **Fire:** Are all necessary fire precautions taken? Is friction taken into account?

The equipment which answers all these questions satisfactorily nearly always will prove the best, although the first cost may be the highest of all considered.

SHAFTING

CLASSES OF SHAFTING.—There are three general classes of shafting, namely: (*a*) " Jack shafts," which are belted direct to the engine; (*b*) " Line shafting," which is belted direct to the jack shaft, the term being applied to the long lines of shafting used for power transmission; (*c*) " Counter-shafting," which is the shafting that receives its power from the line shafting and transmits it through tight and loose pulleys or friction clutches to the various machines.

FRICTION HORSE-POWER OF TRANSMISSION EQUIPMENT.—As an indication of the large amount of power generated by prime movers for manufacturing operations which does not reach the machines, but is consumed by the transmission equipment, the following figures, given by Prof. C. H. Benjamin, " Transactions of A. S. M. E.," and obtained in an investigation of power transmission in a number of factories, are given below:

No.	Nature of Work	Total Length of Line Shaft in Ft.	Diameters of Line Shaft	R. P. M.	No. of Bearings	Total H. P.	H. P. to Drive Machines	H. P. to Drive Shafting	Per Cent. to Drive Shafting	Per Cent. of Full Load
1	Wire Drawing and Polishing	1130	2½, 3¾, 4.6″	170	115	400	243	157	39.2	50
2	Steel Stamping and Polishing	580	3, 3½″	200	68	74	17	57	77	35
3	Boiler and Machine Work...	1530	2½, 3″	150	46	38.6	13.3	25.3	65.6	65
4	Bridge Machinery..........	1460	2½, 3, 4″	110	142	59.2	11.3	47.9	80.7	90
5	Heavy Machine Work......	1130	3″	190	110	112	48	64	57	100
6	Heavy Machine Work......	1065	2, 3, 4″	180 to 150	114	168	77	91	54.2	100
7	Light Machine Work........	748	1½, 1¾, 2.3″	135 to 150	101	40.4	19.7	20.7	51.2	100
8	Manufacturers of Small Tools	500	2, 3″	114	58	74.3	34.3	40	53.8	100
9	Manufacturers of Small Tools	900	2½, 1¾″	175 to 136	102	47.2	22.7	24.5	51.8	100
10	Sewing Machines and Bicycles	2490	2, 6″	150	274	190	82	108	56.9	100
11	Sewing Machines...........	1470	2, 3, 4″	160 to 125	184	107	32.5	74.5	69.7	100
12	Screw Machines and Screws.	1800	2, 2¼, 2½, 3″	180	180	241	127	114	47.3	100
13	Steel Wood Screws.........	674	1½, 2, 3″	160 to 175	96	117	100	17	14.5	25
14	Manufacturers of Steel Nails.	988	2½″	200	74	91.6	45.9	45.7	49.9	100
15	Planing Mill	165	3″	267	19	39.2	10.6	28.6	73	100
16	Light Machine Work.......	275	2″	175	37	8.3	4.3	4.0	48.6	50

The column showing the percentage of power required to drive the shafting, is clearly demonstrative of the vast amount of power consumed by this section of the average plant.

PULLEY SPEEDS.—If the diameters of the driving pulley and the driven pulley are known, and it is desired to know the revolutions of the driven pulley, the following formula may be used:

$$r=\frac{D\times R}{d}\text{ where }\begin{aligned}R&=\text{R. P. M. of driving pulley.}\\D&=\text{Diameter of driving pulley.}\\d&=\text{Diameter of driven pulley.}\\r&=\text{R. P. M. of driven pulley.}\end{aligned}$$

AVERAGE SHAFTING SPEEDS.—The average universal speeds for shafting are as follows:

Woollen mills	300–400 revolutions per minute
Machine shops	125–175 revolutions per minute
Wood-working mills	200–250 revolutions per minute
Cotton mills	300–400 revolutions per minute

APPROXIMATE DISTANCES BETWEEN BEARINGS FOR VARIOUS-SIZED STEEL SHAFTS.—

Diameters, inches.	Bearing Centres, feet and inches.
1	6–0
1 1/2	6–6
2	8–6
2 1/2	10–0
3	11–0
3 1/2	12–0
4	13–0

NOTE. Bearings are generally 8′ 0″ apart.

HANGERS.—When a shaft is suspended from the ceiling, the bearing is usually carried in a cast-iron frame, called a "hanger."

A "hanger," when set on the floor, is called a "floor frame," and when fastened to the wall or to a post is called a "post hanger."

HANGER BEARINGS.—The most important part of a hanger is the bearing. A self-oiling hanger bearing usually contains a ring or chain-feed oiler. Some shafting bearings are lubricated by means of wicking, which feeds oil from a small reservoir. Hangers are usually provided with some method for adjustment, to provide for alignment of the shafting.

ALIGNMENT OF SHAFTING.—One of the largest sources of friction loss in a mill is the line shafting. Often the line shafting losses are as high as 25 per cent. or more of the total power delivered by the engine.

Poor lubrication and bad alignment of the shafting are the chief causes of shafting friction losses.

"**Shafting may be placed in proper alignment**" by the following method, which can be used in the field by the lubricating engineer:

Drop a plumb-line from the two end bearings and locate the indicated points with tacks. Run a line between the two tacks with a chalked string.

At intervals along the chalk-mark drive tacks into the floor, just far enough to hold them steady. By means of a straight-edge and level adjust the tacks until the heads are level.

Make a rod, having a length exactly equal to the distance between the first bearing and the first tack.

By turning the shaft and testing it at the various tacks, each of the shaft bearings may be adjusted, until the rod can be made to just reach between the shaft and the tack heads at all points, indicating alignment.

BALL-BEARING SHAFT HANGERS.—Line shaft hangers are sometimes equipped with ball bearings. Such an equipment will usually result in a great saving of power and give satisfactory results.

COMPARATIVE FRICTION.—Tests on plain babbit, roller-bearing and ball-bearing shaft bearings are given in another section. See Index.

WATER

WATER.—Water has large solvent powers, and when it soaks into the ground it dissolves out some of the constituents of the rocks and soil through which it passes. The substances most generally found in water are the carbonates of calcium and magnesium, and also their sulphates, grease and organic matter (sewage), and acids (particularly in localities where the rivers may receive pumpage from mines).

The calcium and magnesium carbonates give the water the property of hardness (temporary), which will disappear on boiling, due to the driving off of the carbonic gas, which results in precipitation of the carbonates and the softening of the water.

If the water hardness is due to the sulphates of calcium and magnesium, they cannot be removed by boiling.

A typical series of analyses of water from various sources is as follows:

	River Water	Well Water
Magnesium Carbonate	2.80	1.5
Calcium Carbonate	8.72	9.0
Sodium Sulphate	1.43	13.65
Magnesium Sulphate	0.00	7.00
Sodium Chloride	2.70	7.13
Calcium Sulphate	3.90	11.45
Silica	.48	.60
	20.03*	50.33*

* NOTE. The above in grains per gallon.

EFFECT OF HARD WATER ON SOAPS.—Pure water, such as rain water or distilled water, exerts only a solvent action upon soap. However, if calcium and magnesium compounds are present in the water, insoluble lime or magnesium soaps are formed, and these soaps form curdy masses. This is an important feature in connection with maintaining a staple emulsion in the case of soluble cutting oils and compounds, and also in the use of soaps in the wool-scouring process.

Generally, soaps consist of oleate, stearate or palmitate of soda or potash, and the more lime (calcium sulphate) or magnesium in the water, the more soap per volume will be decomposed to give insoluble oleate, stearate or palmitate of lime, or magnesium, such as calcium oleate (which is lime soap).

Lime salts in the water act immediately upon the soap, with the result of precipitating the oleate, stearate or palmitate of lime, but in the case of the magnesium salts, considerable time is required for the reaction to occur. The magnesia salts are a more powerful hardener, however. It has been stated by good authority that each grain of carbonate of lime per gallon of water causes an expenditure of soap equal to about 2 ounces per 100 gallons of water.

PURIFICATION OF WATER.—The lubricating engineer may have occasion from time to time to correct trouble ensuing from the use of hard water for the purpose of forming cutting emulsions with soluble oils or paste compounds, and the resulting tendency of the emulsion to separate, with the danger of causing rusting or stoppage of the feed pipes, due to the formation of the curdy masses.

If the water is charged with carbonate of lime, magnesia or iron, and is treated by boiling, the excess of carbonic acid will be expelled, and the lime or magnesia will to a large extent be deposited at the bottom of the container.

Soda ash or caustic soda may be used to treat the water in case it is very bad.

SPECIFIC HEAT OF WATER.—The following table gives the specific heat of water at various temperatures. (See Index for definition of specific heat.)

Temperature Fahr.	Specific Heat
32° F.	1.0094
104° F.	0.9974
212° F.	1.0101

WEIGHT AND MEASUREMENT OF WATER.—One gallon of pure water at 60° Fahr. weighs 8.34 pounds.

1 cubic foot of water at 32° F. .... 62.418 pounds
1 cubic foot of water at 62° F. .... 62.355 pounds
1 cylindrical foot of water .... 49.1 pounds
1 gallon of water .... 8.34 pounds at 62° F.
1 foot head of water at 62° is equal to a pressure of 0.433 pounds per square inch.
1 pound per square inch is equivalent to a head of water 2.3093 feet in height, at 62° F.
1 cubic foot of water at 32° F. contains 7.48 U. S. gallons.
1 Imperial gallon contains 277.42 cubic inches.
1 Imperial gallon weighs 10 pounds.
1 cubic inch of water weighs .036 pounds.

TREATMENT OF IMPURITIES IN WATER.—The methods of treating water to remove impurities and scale-forming ingredients are divided into two main methods:

(*a*) Chemical treatment, to cause precipitation of the impurities;

(*b*) Heat treatment, which acts to reduce the property of water to hold certain salts in solution.

Generally the heat treatment is used in conjunction with the chemical treatment to assist it, although water, which is "temporarily hard," only requires the heat treatment. ("Temporarily hard water" being water carrying the carbonates of lime and magnesium, which may be precipitated by boiling, when the water then becomes "soft." The temperature required being only about 212° Fahr. "Permanently hard water" is that which chiefly contains calcium sulphate. Calcium sulphate is only precipitated at high temperatures, 300° Fahr. or more.)

The three general chemical methods of water treatment are:

(*a*) *The Soda Treatment:* For water carrying lime and magnesium sulphates, caustic soda and carbonate of soda are used separately or together. In the case of carbonate of soda added to the water, which carries little or no bicarbonates or carbonic acid, the sulphates are decomposed, and insoluble lime or magnesia carbonates are formed and precipitated, while the neutral soda stays in solution. Should bicarbonates or free carbonic acid be in the water treated as above, bicarbonate of lime is formed, and remains in solution unless acted on by heat, in which case the carbon dioxide is driven off and insoluble monocarbonates formed and precipitated. If caustic soda were used instead of carbonate of soda, as above, the action is more active.

(*b*) *Lime Treatment:* For water carrying lime and magnesium bicarbonates, slacked lime in solution is used as a reagent. The action in this case being a combination of the slaked lime in solution (lime water) with the carbonic acid, free or as carbonates, and the subsequent formation of an insoluble lime monocarbonate. The bicarbonates of magnesium and lime, after losing their carbonic acid, become insoluble and precipitate.

(*c*) *Soda and Lime Treatment:* This process is most generally in use where magnesium and lime sulphates are in the water, as well as sufficient bicarbonates and carbonic acid to affect the action of soda. The treatment is based upon adding sufficient soda to break down the lime and magnesia sulphates, and sufficient lime is added as is necessary to absorb the remaining carbonic acid. Common lime and soda are used.

(Where a combination of heat and chemical treatment is used, the "temporary hardness" is removed by heat precipitation of the magnesia and lime carbonates, while the chemical treatment takes care of the sulphates of lime.)

HEAT UNITS PER POUND AND WEIGHT PER CUBIC FOOT OF WATER BETWEEN 32 DEGREES FAHRENHEIT AND 340 DEGREES FAHRENHEIT

Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot	Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot	Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot	Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot	Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot	Temperature degrees Fahrenheit	Heat units per pound	Weight per cubic foot
32	0.00	62.42	70	38.06	62.30	108	75.95	61.90	146	113.86	61.27	184	151.89	60.49	222	190.1	59.58
33	1.01	62.42	71	39.06	62.30	109	76.94	61.88	147	114.86	61.25	185	152.89	60.47	223	191.1	59.55
34	2.01	62.42	72	40.05	62.29	110	77.94	61.86	148	115.86	61.24	186	153.89	60.45	224	192.1	59.53
35	3.02	62.43	73	41.05	62.28	111	78.94	61.85	149	116.86	61.22	187	154.90	60.42	225	193.1	59.50
36	4.03	62.43	74	42.05	62.27	112	79.93	61.83	150	117.86	61.20	188	155.90	60.40	226	194.1	59.48
37	5.04	62.43	75	43.05	62.26	113	80.93	61.82	151	118.86	61.18	189	156.90	60.38	227	195.2	59.45
38	6.04	62.43	76	44.04	62.26	114	81.93	61.80	152	119.86	61.16	190	157.91	60.36	223	196.2	59.42
39	7.05	62.43	77	45.04	62.25	115	82.92	61.79	153	120.86	61.14	191	158.91	60.33	229	197.2	59.40
40	8.05	62.43	78	46.04	62.24	116	83.92	61.77	154	121.86	61.12	192	159.91	60.31	230	198.2	59.37
41	9.05	62.43	79	47.04	62.23	117	84.92	61.75	155	122.86	61.10	193	160.91	60.29	231	199.2	59.34
42	10.06	62.43	80	48.03	62.22	118	85.92	61.74	156	123.86	61.08	194	161.92	60.27	232	200.2	29.32
43	11.06	62.43	81	49.03	62.21	119	86.91	61.72	157	124.86	61.06	195	162.92	60.24	233	201.2	59.29
44	12.06	62.43	82	50.03	62.20	120	87.91	61.71	158	125.86	61.04	196	163.92	60.22	234	202.2	59.27
45	13.07	62.42	83	51.02	62.19	121	88.91	61.69	159	126.86	61.02	197	164.93	60.19	235	203.2	59.24
46	14.07	62.42	84	52.02	62.18	122	89.91	61.68	160	127.86	61.00	198	165.93	60.17	236	204.2	59.21
47	15.07	62.42	85	53.02	62.17	123	90.90	61.66	161	128.86	60.98	199	166.94	60.15	237	205.3	59.19
48	16.07	62.42	86	54.01	62.16	124	91.90	61.65	162	129.86	60.96	200	167.94	60.12	238	206.3	59.16
49	17.08	62.42	87	55.01	62.15	125	92.90	61.63	163	130.86	60.94	201	168.94	60.10	239	207.3	59.14
50	18.08	62.42	88	56.01	62.14	126	93.90	61.61	164	131.86	60.92	202	169.95	60.07	240	208.3	59.11
51	19.08	62.41	89	57.00	62.13	127	94.89	61.59	165	132.86	60.90	203	170.95	60.05	241	209.3	59.08
52	20.08	62.41	90	58.00	62.12	128	95.89	61.58	166	133.86	60.88	204	171.96	60.02	242	210.3	59.05
53	21.08	62.41	91	59.00	62.11	129	96.89	61.56	167	134.86	60.86	205	172.96	60.00	243	211.4	59.03
54	22.08	62.40	92	60.00	62.09	130	97.89	61.55	168	135.86	60.84	206	173.97	59.98	244	212.4	59.00
55	23.08	62.40	93	60.99	62.08	131	98.89	61.53	169	136.86	60.82	207	174.97	59.95	245	213.4	58.97
56	24.08	62.39	94	61.99	62.07	132	99.88	61.52	170	137.87	60.80	208	17[illegible].98	59.93	246	214.4	58.94
57	25.08	62.39	95	62.99	62.06	133	100.88	61.50	171	138.87	60.78	209	176.98	59.90	247	215.4	58.91
58	26.08	62.38	96	63.98	62.05	134	101.88	61.49	172	139.87	60.76	210	177.99	59.88	248	216.4	58.89
59	27.08	62.37	97	64.98	62.04	135	102.88	61.47	173	140.87	60.73	211	178.99	59.85	249	217.4	58.86
60	28.08	62.37	98	65.98	62.03	136	103.88	61.45	174	141.87	60.71	212	180.00	59.83	250	218.5	58.83
61	29.08	62.36	99	66.97	62.02	137	104.87	61.43	175	142.87	60.69	213	181.0	59.80	260	228.6	58.55
62	30.08	62.36	100	67.97	62.00	138	105.87	61.41	176	143.87	60.67	214	182.0	59.78	270	238.8	58.26
63	31.07	62.35	101	68.97	61.99	139	106.87	61.40	177	144.88	60.65	215	183.0	59.75	280	249.0	57.96
64	32.07	62.35	102	69.96	61.98	140	107.87	61.38	178	145.88	60.62	216	184.0	59.73	290	259.3	57.65
65	33.07	62.34	103	70.96	61.97	141	108.87	61.36	179	146.88	60.60	217	185.0	59.70	300	269.6	57.33
66	34.07	62.33	104	71.96	61.95	142	109.87	61.34	180	147.88	60.58	218	186.1	59.68	310	279.9	57.00
67	35.07	62.33	105	72.95	61.94	143	110.87	61.33	181	148.88	60.56	219	187.1	59.65	320	290.2	56.66
68	36.07	62.32	106	73.95	61.93	144	111.87	61.31	182	149.89	60.53	220	188.1	59.63	330	300.6	56.30
69	37.06	62.31	107	74.95	61.91	145	112.86	61.29	183	150.89	60.51	221	189.1	59.60	340	311.0	55.94

STEAM AND IMPURITIES IN FEED WATER.—An interesting report of an investigation as to the cause of certain hard and sticky deposits found in the various steam cylinders, including locomotives, of a large industrial plant, is given in *The Atlantic Lubricator* by Mr. T. A. Mayes. The report is an illustration of the importance of investigating the boiler feed water, in adjusting steam cylinder deposits, usually blamed on the cylinder oil. An analysis of the deposits as taken from the cylinders is given in Table I. An analysis of the solids from the waste water is shown in Table II. The feed water analysis is given in Table III. The column water analysis is in Table IV. Table V gives an analysis of the condensate taken from a special condenser rigged up in the exhaust line of a large unit. It was evident that the same solids that were going into the boilers in the feed water were being carried past the engines in the steam. The boilers were supplied with raw water from a river and the intake was directly below the waste water discharge. The remedy was found in more frequent blow-downs and the water in the boiler carried at a lower level. The groaning of the valves and poor lubrication was thus remedied.

Table I

	Residue from 400 lb. pressure hydraulic pump 100 lbs. boiler pressure	Residue from locomotives. 175 lb. boiler pressure
Oil	26.0%	20.5%
Asphalt	0.5%	0.7%
Volatile Matter	14.4%	17.0%
Fixed Carbon (C)	23.1%	18.1%
Silicon (SiO_2)	4.1%	7.0%
Ferric Oxide (Fe_2O_3)	24.1%	34.1%
Aluminum Oxide (Al_2O_3)	2.2%	1.3%
Calcium Oxide (CaO)	2.5%	0.6%
Magnesium Oxide (MgO)	2.6%	0.5%
Manganese Oxide (MnO_2)	0.5%	0.2%

Table II

Carbon (C)	2.2%
Silicon (SiO_2)	6.9%
Iron and Aluminum Oxide (R_2O_3)	83.3%
Calcium Oxide (CaO)	4.5%
Magnesium Oxide (MgO)	2.3%
Manganese Oxide (MnO_2)	0.8%

Table III

	Parts per million.
Total Solids	89.0
Organic Matter	8.0
Silicon (SiO)	7.4
Iron and Aluminum Oxide (R_2O_3)	0.4
Calcium Oxide (CaO)	20.8
Magnesium Oxide (MgO)	5.8
Chlorine (Cl)	17.9
Sulphur Trioxide (SO_3)	15.0

Table IV

	Parts per million
Total Solids	2,028.0
Organic Matter	289.8
Silicon (SiO_2)	42.2
Iron and Aluminum Oxide (R_2O_3)	0.2
Calcium Oxide (CaO)	57.4
Magnesium Oxide (MgO)	65.8
Chlorine (Cl)	539.6
Sulphur Trioxide (SO_3)	188.7

Table V

Condensed water

	Parts per million
Total Solids	38.0
Organic Matter	10.0
Silicon (SiO_2)	2.4
Iron and Aluminum Oxide (R_2O_3)	0.4
Calcium Oxide (CaO)	4.0
Magnesium Oxide (MgO)	3.3
Chlorine (Cl)	14.0
Sulphur Trioxide (SO_3)	1.4

STEAM

SATURATED STEAM.—Steam that is formed in a closed vessel in contact with water is called saturated steam. It has a different density and pressure for each temperature. Dry saturated steam is steam that carries no water in suspension.

SUPERHEATED STEAM.—If more heat is added to the steam after all of the water it contains has been transferred into steam, the temperature of the steam will be greater than that of ordinary saturated steam having the same pressure. The steam is then said to be superheated. The number of degrees of temperature by which the superheated steam temperature exceeds the temperature of saturated steam at the same pressure is called the "degree of superheat."

* **PRIMING.**—Saturated steam may carry a percentage of water in it. It would then be called wet saturated steam. Steam produced in boilers where the hot gases are not in contact with the surface surrounding the steam, will nearly always be "primed" or wet.

This priming or wetness may vary from about 1/10 of 1 per cent. to about 3 or 4 per cent.

ATMOSPHERIC PRESSURE.—For general engineering purposes, atmospheric pressure is considered as 14.7 pounds per square inch.

When the steam gauge of a boiler is read, this pressure indicated is above atmospheric pressure. Therefore, if "absolute pressure" is desired, 14.7 pounds must be added to the gauge reading.

FLOW OF STEAM IN MAINS.—Steam pipes and mains are usually designed to allow for short pipes, about 6000 feet per minute velocity. For medium length pipes about 5000 feet per minute. For long pipes about 4000 feet per minute.

STEAM TABLES

TABLE OF THE PROPERTIES OF SATURATED STEAM.—In the tables of the properties of Saturated Steam, which follow, the figures are taken by permission from Marks & Davis' "Steam Tables and Diagrams."

The heat necessary to raise one pound of water from 32° F. to the boiling-point, or point of ebullition, is called the "*Heat of the Liquid.*"

The heat absorbed to change the liquid to steam, and to overcome the opposition to increase in volume, is called the "*Latent Heat of Evaporation.*"

The sum of "Heat of the Liquid" and the "Latent Heat of Evaporation" make up the "*Total Heat of Steam.*"

The "Heat of the Liquid," the "Latent Heat of Evaporation," and the "Total Heat of the Steam" are measured in "B. T. U." (British Thermal Units). (See index.)

The "*Specific Volume of Saturated Steam*" is the volume expressed in cubic feet, of one pound of steam at the pressure indicated.

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* Note. Priming, or passing off the steam from a boiler in "spasmodic puffs," may be caused by a concentration of sodium carbonate, sodium chloride, or sodium sulphate in solution. The sodium sulphate may be found in water from certain Southern sections and in other waters where calcium or magnesium sulphate has been precipitated with soda ash. The boiler should be frequently blown down.

In computing results of boiler tests, etc., the feed-water temperature and steam pressure will be found to vary with different tests; and, as a means of reducing all results to a common basis for the purpose of comparison, the evaporation, under the actual test conditions of the steam pressure and feed-water temperature is changed, by means of a factor called the "*factor of evaporation*," to an "*equivalent evaporation*" under standard conditions. The standard conditions referred to assume a feed-water temperature of 212° F. and a steam pressure of 14.7 pounds per square inch (absolute), which pressure equals normal atmospheric pressure at the level of the sea.

Thus *equivalent evaporation* assumes that the steam is generated *from* water at 212° F. (which is the boiling-point of water at sea level), and steam generated is at 212° F. Thus we speak of *equivalent evaporation from and at 212° F.*

Steam gauges on boilers indicate pressure above atmospheric pressure. The pressures used in the steam tables are "*Absolute Pressures*," which are equal to the "*Gauge Pressure*" plus 14.7 pounds per square inch (atmospheric pressure) at the sea level. At other places, above or below sea level, for accurate results, the atmospheric pressure must be determined from the barometer reading at the place in question.

To illustrate the use of the tables, assume that in a boiler trial the temperature of the feed water was 65° F. and the steam pressure 165.3 pounds per square inch by the gauge. ($165.3 + 14.7 = 180.0$ pounds *pressure absolute*.) At 180 pounds absolute pressure, the "total heat of one pound of steam" is, from the table, 1196.4 B. T. U., considering it as being measured from the standard temperature of 32° F. The feed water in this case, however, was at 65° F., at which temperature, from the Table of Heats and Weights of Water, it is found to contain 33.07 Heat Units per pound, measured above 32° F.

Therefore, under these conditions, there is added to each pound of the steam ($1196.4 - 33.07 = 1163.33$ B. T. U.). Under the "*Standard Conditions*," as previously described, only 970.4 B. T. U. are required to evaporate one pound of water, this being the latent heat of evaporation at 212° F. (see index), and is explained by the fact that 1150.4 B. T. U. is the total heat of a pound of steam at a temperature of 212° F.; and since one pound of water at 212° F. contains 180 B. T. U. heat units per pound (see table), then under the standard conditions (from and at 212° F.), $1150.4 - 180 = 970.4$, which represents the number of B. T. U. required to change one pound of water at 212° F. into steam under atmospheric pressure and without raising the temperature. (This is another definition of the "Latent Heat of Evaporation.")

The ratio between the heat actually added, which, in this case, is 1163.33 B. T. U., and the heat required at standard conditions, from and at 212° F., which is 970.4, determines the "Factor of Evaporation."

Thus: $\frac{1163.33}{970.4} = 1.1988 =$ *Factor of Evaporation for the Assumed Conditions.*

If the same quantity of heat had been taken up and absorbed under the standard conditions, as in the trial condition, 1.1988 times the amount of steam would have been generated.

PROPERTIES OF SATURATED STEAM

(Reproduced by permission from Marks & Davis, "Steam Tables and Diagrams.")

Pressure, pounds absolute	Temperature degrees F.	Specific volume cu. ft. per pound	Heat of the liquid, B. t. u.	Latent heat of evap., B. t. u.	Total heat of steam, B. t. u.	Pressure, pounds absolute
1	101.83	333.0	69.8	1034.6	1104.4	1
2	126.15	173.5	94.0	1021.0	1115.0	2
3	141.52	118.5	109.4	1012.3	1121.6	3
4	153.01	90.5	120.9	1005.7	1126.5	4
5	162.28	73.33	130.1	1000.3	1130.5	5
6	170.06	61.89	137.9	995.8	1133.7	6
7	176.85	53.56	144.7	991.8	1136.5	7
8	182.86	47.27	150.8	988.2	1139.0	8
9	188.29	42.36	156.2	985.0	1141.1	9
10	193.22	38.38	161.1	982.0	1143.1	10
11	197.75	35.10	165.7	979.2	1144.9	11
12	201.96	32.36	169.9	976.6	1146.5	12
13	205.87	30.33	173.8	974.2	1148.0	13
14	209.55	28.02	177.5	971.9	1149.4	14
15	213.0	26.27	181.0	969.7	1150.7	15
16	216.3	24.79	184.4	967.6	1152.0	16
17	219.4	23.38	187.5	965.6	1153.1	17
18	222.4	22.16	190.5	963.7	1154.2	18
19	225.2	21.07	193.4	961.8	1155.2	19
20	228.0	20.08	196.1	960.0	1156.2	20
22	233.1	18.37	201.3	956.7	1158.0	22
24	237.8	16.93	206.1	953.5	1159.6	24
26	242.2	15.72	210.6	950.6	1161.2	26
28	246.4	14.67	214.8	947.8	1162.6	28
30	250.3	13.74	218.8	945.1	1163.9	30
32	154.1	12.93	222.6	942.5	1165.1	32
34	257.6	12.22	226.2	940.1	1166.3	34
36	261.0	11.58	229.6	937.7	1167.3	36
38	264.2	11.01	232.9	935.5	1168.4	38
40	267.3	10.49	236.1	933.3	1169.4	40
42	270.2	10.02	239.1	931.2	1170.3	42
44	273.1	9.59	242.0	929.2	1171.2	44
46	275.8	9.20	244.8	927.2	1172.0	46
48	278.5	8.84	247.5	925.3	1172.8	48
50	281.0	8.51	250.1	923.5	1173.6	50
52	283.5	8.20	252.6	921.7	1174.3	52
54	285.9	7.91	255.1	919.9	1175.0	54
56	288.2	7.65	257.5	918.2	1175.7	56
58	290.5	7.40	259.8	916.5	1176.4	58
60	292.7	7.17	262.1	914.9	1177.0	60
62	294.9	6.95	264.3	913.3	1177.6	62
64	297.0	6.75	266.4	911.8	1178.2	64
66	299.0	6.56	268.5	910.2	1178.8	66
68	301.0	6.38	270.6	908.7	1179.3	68

PROPERTIES OF SATURATED STEAM—(Continued)

Pressure, pounds absolute	Temperature degrees F.	Specific volume cu. ft. per pound	Heat of the liquid, B. t. u.	Latent heat of evap., B. t. u.	Total heat of steam, B. t. u.	Pressure, pounds absolute
70	302.9	6.20	272.6	907.2	1179.8	70
72	304.8	6.04	274.5	905.8	1180.4	72
74	306.7	5.89	276.5	904.4	1180.9	74
76	308.5	5.74	278.3	903.0	1181.4	76
78	310.3	5.60	280.2	901.7	1181.8	78
80	312.0	5.47	282.0	900.3	1182.3	80
82	313.8	5.34	283.8	899.0	1182.8	82
84	315.4	5.22	285.5	897.7	1183.2	84
86	317.1	5.10	287.2	896.4	1183.6	86
88	318.7	5.00	288.9	895.2	1184.0	88
90	320.3	4.89	290.5	893.9	1184.3	90
92	321.8	4.79	292.1	892.7	1184.8	92
94	323.4	4.69	293.7	891.5	1185.2	94
96	324.9	4.60	295.3	890.3	1185.6	96
98	326.4	4.51	296.8	889.2	1186.0	98
100	327.8	4.429	298.3	888.0	1186.4	100
105	331.4	4.230	302.0	885.2	1187.2	105
110	334.8	4.047	305.5	882.5	1188.0	110
115	338.1	3.880	309.0	879.8	1188.8	115
120	341.3	3.726	312.3	877.2	1189.6	120
125	344.4	3.583	315.5	874.7	1190.3	125
130	347.4	3.452	318.6	872.3	1191.0	130
135	350.3	3.331	321.7	869.9	1191.6	135
140	353.1	3.219	324.6	867.6	1192.2	140
145	355.8	3.112	327.4	865.4	1192.8	145
150	358.5	3.012	330.2	863.2	1193.4	150
155	361.0	2.920	332.9	861.0	1194.0	155
160	363.6	2.834	335.6	858.8	1194.5	160
165	366.0	2.753	338.2	856.8	1195.0	165
170	368.5	2.675	340.7	854.7	1195.4	170
175	370.8	2.602	343.2	852.7	1195.9	175
180	373.1	2.533	345.6	850.8	1196.4	180
185	375.4	2.468	348.0	848.8	1196.8	185
190	377.6	2.406	350.4	846.9	1197.3	190
195	379.8	2.346	352.7	845.0	1197.7	195
200	381.9	2.290	354.9	843.2	1198.1	200
205	384.0	2.237	357.1	841.4	1198.5	205
210	386.0	2.187	359.2	839.6	1198.8	210
215	388.0	2.138	361.4	837.9	1199.2	215
220	389.9	2.091	363.4	836.2	1199.6	220
225	391.9	2.046	365.5	834.4	1199.9	225
230	393.8	2.004	367.5	832.8	1200.2	230
235	395.6	1.964	369.4	831.1	1200.6	235
240	397.4	1.924	371.4	829.5	1200.9	240
245	399.3	1.887	373.3	827.9	1201.2	245
250	401.1	1.850	375.2	826.3	1201.5	250

SATURATED STEAM AND VARYING VACUUM.—The table below gives the properties of Saturated Steam, including the temperature, pressure, heat of the liquid above 32° F., latent heat above 32° F., total heat above 32° F., in B. T. U., and the density per cubic foot, in pounds, for various amounts of vacuum. The table is calculated from tables by Marks & Davis, which are widely accepted as the most accurate.

PROPERTIES OF SATURATED STEAM FOR VARYING AMOUNTS OF VACUUM

(Calculated from Marks and Davis Tables)

Vacuum ins. Hg.	Absolute pressure pounds	Temperature degrees Fahrenheit	Heat of the liquid above 32 degrees B. t. u.	Latent heat above 32 degrees B. t. u.	Total heat above 32 degrees B. t. u.	Density or weight per cubic foot pounds
29.5	.207	54.1	22.18	1061.0	1083.2	0.000678
29	.452	76.6	44.64	1048.7	1093.3	0.001415
28.5	.698	90.1	58.09	1041.1	1099.2	0.002137
28	.944	99.9	67.87	1035.6	1103.5	0.002843
27	1.44	112.5	80.4	1028.6	1109.0	0.00421
26	1.93	124.5	92.3	1022.0	1114.3	0.00577
25	2.42	132.6	100.5	1017.3	1117.8	0.00689
24	2.91	140.1	108.0	1013.1	1121.1	0.00821
22	3.89	151.7	119.6	1006.4	1126.0	0.01078
20	4.87	161.1	128.9	1001.0	1129.9	0.01331
18	5.86	168.9	136.8	996.4	1133.2	0.01581
16	6.84	175.8	143.6	992.4	1136.0	0.01827
14	7.82	181.8	149.7	9.888	1138.5	0.02070
12	8.80	187.2	155.1	985.6	1140.7	0.02312
10	9.79	192.2	160.1	982.6	1142.7	0.02554
5	12.24	202.9	170.8	976.0	1146.8	0.03148

Gauges for indicating the amount of vacuum are called "Vacuum Gauges," and give the difference between the atmospheric pressure and the pressure which exists within the vessel to which the gauge is attached (such as condenser) in inches of mercury.

The equivalent to a pressure of one pound per square inch is represented by 2.0353 inches of mercury, and for ordinary purposes the figure 2.04 can be used for calculation. Where the reading of the vacuum gauge is in inches, the absolute pressure for any barometer reading will be $\frac{(A-R)}{2.04}$

Where $A =$ Barometer reading in inches.

$R =$ Reading of vacuum gauge in inches.

$2.04 =$ Mercury height corresponding to a pressure of one pound per square inch.

Thus, if the barometer reading is 29.8 inches, and the vacuum gauge reading is 24 inches, the absolute pressure can be computed as follows:

$$\frac{29.8-24}{2.04} = \frac{5.8}{2.04} = 2.84 \text{ pounds per square inch.}$$

SUPERHEAT STEAM TABLES.—The table on page 84, reproduced from "Steam Tables and Diagrams," by Marks & Davis, by permission of the Authors, and Longmans, Green & Company, Publishers, gives the Properties of Superheated Steam for Various Degrees of Superheat and Pressure.

FACTOR OF EVAPORATION, SUPERHEATED STEAM.—The factor of evaporation, where superheated steam is generated in a boiler test, and calculations are to be made, can be determined from the Superheat Steam Tables, as shown by the following formula:

$$\text{Factor of evaporation} = \frac{H-h}{\text{Lat.}}$$

Where H = Total heat in one pound of superheated steam from the Superheated Steam Table.

h = Sensible heat of feed water above 32° F. from Water Table.

Lat. = 970.4 Latent heat of evaporation of one pound of saturated steam at atmospheric pressure.

ADVANTAGES OF USING SUPERHEATED STEAM.—These may be briefly outlined as follows:

(*a*) *Results in a saving of wear and tear,* due to lower ratings at which the boiler may be operated, or the same number of boiler horse-power can be obtained from a smaller number of boilers. Thus a saving due to increased boiler efficiency is obtained.

(*b*) *Absence of water* in the steam mains.

(*c*) *The power to give up its heat to surrounding bodies is less for superheated steam than for saturated steam,* so its steam will not be given up so rapidly to the pipe walls as if saturated steam were passing through the pipes. If the mains are well insulated, the heat radiation loss, when carrying superheated steam, only results in a lowering of the superheat, so that if it is high enough at the boiler, there can be a large radiation loss and dry or superheated steam will still be delivered to the engine.

(*d*) When steam enters a steam-engine cylinder, it must give up heat to warm the cylinder walls, which have been cooled by the steam exhausted during the previous stroke. If the steam entering be "saturated steam," then the giving up of heat to the cylinder walls results in condensation, which so-called "initial condensation" may range about 25 per cent. to 30 per cent. of the total weight of steam supplied. If the steam entering is superheated, it can lose its superheat before condensation will begin.

(*e*) *The use of superheated steam results in a saving in the heat consumption of an engine,* and thus reduces the demand on the boiler, which involves a better fuel consumption per horse-power.

(*f*) With *steam turbines,* superheated steam reduces the action of water erosion upon the turbine blades; which would occur with the use of saturated steam. Water in the low-pressure turbines stages is reduced with superheated steam. Roughly, with an economical turbine, a 100° superheat gives about 3 per cent. coal saving, with equal boiler efficiency.

PROPERTIES OF SUPERHEATED STEAM

(Reproduced by permission from Marks and Davis " Steam Tables and Diagrams ")

Pressure pounds absolute		Saturated steam	Degrees of superheat 50	100	150	200	250	300		Pressure pounds absolute
	t	162.3	212.3	262.3	312.3	362.3	412.3	462.3	t	
5	v	73.3	79.7	85.7	91.8	97.8	103.8	109.8	v	5
	h	1130.5	1153.5	1176.4	1199.5	1222.5	1245.6	1268.7	h	
	t	193.2	243.2	293.2	343.2	393.2	443.2	493.2	t	
10	v	38.4	41.5	44.6	47.7	50.7	53.7	56.7	v	10
	h	1143.1	1166.3	1189.5	1212.7	1236.0	1259.3	1282.5	h	
	t	213.0	263.0	313.0	363.0	413.0	463.0	513.0	t	
15	v	26.27	28.40	30.46	32.50	34.53	36.56	38.58	v	15
	h	1150.7	1174.2	1197.6	1221.0	1244.4	1267.7	1291.1	h	
	t	228.0	278.0	328.0	378.0	428.0	478.0	528.0	t	
20	v	20.08	21.69	23.25	24.80	26.33	27.85	29.37	v	20
	h	1156.2	1179.9	1203.5	1227.1	1250.6	1274.1	1297.6	h	
	t	240.1	290.1	340.1	390.1	440.1	490.1	540.1	t	
25	v	16.30	17.60	18.86	20.10	21.32	22.55	23.77	v	25
	h	1160.4	1184.4	1208.2	1231.9	1255.6	1279.2	1302.8	h	
	t	250.4	300.4	350.4	400.4	450.4	500.4	550.4	t	
30	v	13.74	14.83	15.89	16.93	17.97	18.99	20.00	v	30
	h	1163.9	1188.1	1212.1	1236.0	1259.7	1283.4	1307.1	h	
	t	259.3	309.3	359.3	409.3	459.3	509.3	559.3	t	
35	v	11.89	12.85	13.75	14.65	15.54	16.42	17.30	v	35
	h	1166.8	1191.3	1215.4	1239.4	1263.3	1287.1	1310.8	h	
	t	267.3	317.3	367.3	417.3	467.3	517.3	567.3	t	
40	v	10.49	11.33	12.13	12.93	13.70	14.48	15.25	v	40
	h	1169.4	1194.0	1218.4	1242.4	1266.4	1290.3	1314.1	h	
	t	274.5	324.5	374.5	424.5	474.5	524.5	574.5	t	
45	v	9.39	10.14	10.86	11.57	12.27	12.96	13.65	v	45
	h	1171.6	1196.6	1221.0	1245.2	1269.3	1293.2	1317.0	h	
	t	281.0	331.0	381.0	431.0	481.0	531.0	581.0	t	
50	v	8.51	9.19	9.84	10.48	11.11	11.74	12.36	v	50
	h	1173.6	1198.8	1223.4	1247.7	1271.8	1295.8	1319.7	h	
	t	287.1	337.1	387.1	437.1	487.1	537.1	587.1	t	
55	v	7.78	8.40	9.00	9.59	10.16	10.73	11.30	v	55
	h	1175.4	1200.8	1225.6	1250.0	1274.2	1298.1	1322.0	h	
	t	292.7	342.7	392.7	442.7	492.7	542.7	592.7	t	
60	v	7.17	7.75	8.30	8.84	9.36	9.89	10.41	v	60
	h	1177.0	1202.6	1227.6	1252.1	1276.4	1300.4	1324.3	h	
	t	298.0	348.0	398.0	448.0	498.0	548.0	598.0	t	
65	v	6.65	7.20	7.70	8.20	8.69	9.17	9.65	v	65
	h	1178.5	1204.4	1229.5	1254.0	1278.4	1302.4	1326.4	h	
	t	302.9	352.9	402.9	452.9	502.9	552.9	602.9	t	
70	v	6.20	6.71	7.18	7.65	8.11	8.56	9.01	v	70
	h	1179.8	1205.9	1231.2	1255.8	1280.2	1304.3	1328.3	h	
	t	307.6	357.6	407.6	457.6	507.6	557.6	607.6	t	
75	v	5.81	6.28	6.73	7.17	7.60	8.02	8.44	v	75
	h	1181.1	1207.5	1232.8	1257.5	1282.0	1306.1	1330.1	h	
	t	312.0	362.0	412.0	462.0	512.0	562.0	612.0	t	
80	v	5.47	5.92	6.34	6.75	7.17	7.56	7.95	v	80
	h	1182.3	1208.8	1234.3	1259.0	1283.6	1307.8	1331.9	h	
	t	316.3	366.3	416.3	466.3	516.3	566.3	616.3	t	
85	v	5.16	5.59	6.99	6.38	6.76	7.14	7.51	v	85
	h	1183.4	1210.2	1235.8	1260.6	1285.2	1309.4	1333.5	h	

t = Temperature, degrees Fahrenheit.
v = Specific volume, in cubic feet, per pound.
h = Total heat from water at 32 degrees. B. t. u.

PROPERTIES OF SUPERHEATED STEAM—(Continued)

Pressure pounds absolute		Saturated steam	Degrees of superheat							Pressure pounds absolute
			50	100	150	200	250	300		
	t	320.3	370.3	420.3	470.3	520.3	570.3	620.3	t	
90	v	4.89	5.29	5.67	6.04	6.40	6.76	7.11	v	90
	h	1184.4	1211.4	1237.2	1262.0	1286.6	1310.8	1334.9	h	
	t	324.1	374.1	424.1	474.1	524.1	574.1	624.1	t	
95	v	4.65	5.03	5.39	5.74	6.09	6.43	6.76	v	95
	h	1185.4	1212.6	1238.4	1263.4	1288.1	1312.3	1336.4	h	
	t	327.8	377.8	427.8	477.8	527.8	577.8	627.8	t	
100	v	4.43	4.79	5.14	5.47	5.80	6.12	6.44	v	100
	h	1186.3	1213.8	1239.7	1264.7	1289.4	1313.6	1337.8	h	
	t	331.4	381.4	431.4	481.4	531.4	581.4	631.4	t	
105	v	4.23	4.58	4.91	5.23	5.54	5.85	6.15	v	105
	h	1187.2	1214.9	1240.8	1265.9	1290.6	1314.9	1339.1	h	
	t	334.8	384.8	434.8	484.8	534.8	584.8	634.8	t	
110	v	4.05	4.38	4.70	5.01	5.31	5.61	5.90	v	110
	h	1188.0	1215.9	1242.0	1267.1	1291.9	1316.2	1340.4	h	
	t	338.1	388.1	438.1	488.1	538.1	588.1	638.1	t	
115	v	3.88	4.20	4.51	4.81	5.09	5.38	5.66	v	115
	h	1188.8	1216.9	1243.1	1268.2	1293.0	1317.3	1341.5	h	
	t	341.3	391.3	441.3	491.3	541.3	591.3	641.3	t	
120	v	3.73	4.04	4.33	4.62	4.89	5.17	5.44	v	120
	h	1189.6	1217.9	1244.1	1269.3	1294.1	1318.4	1342.7	h	
	t	344.4	394.4	444.4	494.4	544.4	594.4	644.4	t	
125	v	3.58	3.88	4.17	4.45	4.71	4.97	5.23	v	125
	h	1190.3	1218.8	1245.1	1270.4	1295.2	1319.5	1343.8	h	
	t	347.4	397.4	447.4	497.4	547.4	597.4	647.4	t	
130	v	3.45	3.74	4.02	4.28	4.54	4.80	5.05	v	130
	h	1191.0	1219.7	1246.1	1271.4	1296.2	1320.6	1344.9	h	
	t	350.3	400.3	450.3	500.3	550.3	600.3	650.3	t	
135	v	3.33	3.61	3.88	4.14	4.38	4.63	4.87	v	135
	h	1191.6	1220.6	1247.0	1272.3	1297.2	1321.6	1345.9	h	
	t	353.1	403.1	453.1	503.1	553.1	603.1	653.1	t	
140	v	3.22	3.49	3.75	4.00	4.24	4.48	4.71	v	140
	h	1192.2	1221.4	1248.0	1273.3	1298.2	1322.6	1346.9	h	
	t	355.8	405.8	455.8	505.8	555.8	605.8	655.8	t	
145	v	3.12	3.38	3.63	3.87	4.10	4.33	4.56	v	145
	h	1192.8	1222.2	1248.8	1274.2	1299.1	1323.6	1347.9	h	
	t	358.5	408.6	458.5	508.5	558.5	608.5	658.5	t	
150	v	3.01	3.27	3.51	3.75	3.97	4.19	4.41	v	150
	h	1193.4	1223.0	1249.6	1275.1	1300.0	1324.5	1348.8	h	
	t	361.0	411.0	461.0	511.0	561.0	611.0	661.0	t	
155	v	2.92	3.17	3.41	3.63	3.85	4.06	4.28	v	155
	h	1194.0	1223.6	1250.5	1276.0	1300.8	1325.3	1349.7	h	
	t	363.6	413.6	463.6	513.6	563.6	613.6	663.6	t	
160	v	2.83	3.07	3.30	3.53	3.74	3.95	4.15	v	160
	h	1194.5	1224.5	1251.3	1276.8	1301.7	1326.2	1350.6	h	
	t	366.0	416.0	466.0	516.0	566.0	616.0	666.0	t	
165	v	2.75	2.99	3.21	3.43	3.64	3.84	4.04	v	165
	h	1195.0	1225.2	1252.0	1277.6	1302.5	1327.1	1351.5	h	
	t	368.5	418.5	468.5	518.5	568.5	618.5	668.5	t	
170	v	2.68	2.91	3.12	3.34	3.54	3.73	3.92	v	170
	h	1195.4	1225.9	1252.8	1278.4	1303.3	1327.9	1352.3	h	

t = Temperature, degrees Fahrenheit.
v = Specific volume, in cubic feet, per pound.
h = Total heat from water at 32 degrees, B. t. u.

PROPERTIES OF SUPERHEATED STEAM—(Continued)

Pressure pounds absolute		Saturated Steam	Degrees of superheat 50	100	150	200	250	300		Pressure pounds absolute
	t	370.8	420.8	470.8	520.8	570.8	620.8	670.8	t	
175	v	2.60	2.83	3.04	3.24	3.44	3.63	3.82	v	175
	h	1195.9	1226.6	1253.6	1279.1	1304.1	1328.7	1353.2	h	
	t	373.1	423.1	473.1	523.1	573.1	623.1	673.1	t	
180	v	2.53	2.75	2.96	3.16	3.35	3.54	3.72	v	180
	h	1196.4	1227.2	1254.3	1279.9	1304.8	1329.5	1353.9	h	
	t	375.4	425.4	475.4	525.4	575.4	625.4	675.4	t	
185	v	2.47	2.68	2.89	3.08	3.27	3.45	3.63	v	185
	h	1196.8	1227.9	1255.0	1280.6	1305.6	1330.2	1354.7	h	
	t	377.6	427.6	477.6	527.6	577.6	627.6	677.6	t	
190	v	2.41	2.62	2.81	3.00	3.19	3.37	3.55	v	190
	h	1197.3	1228.6	1255.7	1281.3	1306.3	1330.9	1355.5	h	
	t	379.8	429.8	479.8	529.8	579.8	629.8	679.8	t	
195	v	2.35	2.55	2.75	2.93	3.11	3.29	3.46	v	195
	h	1197.7	1229.2	1256.4	1282.0	1307.0	1331.6	1356.2	h	
	t	381.9	431.9	481.9	531.9	581.9	631.9	681.9	t	
200	v	2.29	2.49	2.68	2.86	3.04	3.21	3.38	v	200
	h	1198.1	1229.8	1257.1	1282.6	1307.7	1332.4	1357.0	h	
	t	384.0	434.0	484.0	534.0	584.0	634.0	684.0	t	
205	v	2.24	2.44	2.62	2.80	2.97	3.14	3.30	v	205
	h	1198.5	1230.4	1257.7	1283.3	1308.3	1333.0	1357.7	h	
	t	386.0	436.0	486.0	536.0	586.0	636.0	686.0	t	
210	v	2.19	2.38	2.56	2.74	2.91	3.07	3.23	v	210
	h	1198.8	1231.0	1258.4	1284.0	1309.0	1333.7	1358.4	h	
	t	388.0	438.0	488.0	538.0	588.0	638.0	688.0	t	
215	v	2.14	2.33	2.51	2.6	2.84	3.00	3.16	v	215
	h	1199.2	1231.6	1259.0	1284.6	1309.7	1334.4	1359.1	h	
	t	389.9	439.9	489.9	539.9	589.9	639.9	689.9	t	
220	v	2.09	2.28	2.45	2.62	2.78	2.94	3.10	v	220
	h	1199.6	1232.2	1259.6	1285.2	1310.3	1335.1	1359.8	h	
	t	391.9	441.9	491.9	541.9	591.9	641.9	691.9	t	
225	v	2.05	2.23	2.40	2.57	2.72	2.88	3.03	v	225
	h	1199.9	1232.7	1260.2	1285.9	1310.9	1335.7	1360.3	h	
	t	393.8	443.8	493.8	543.8	593.8	643.8	693.8	t	
230	v	2.00	2.18	2.35	2.51	2.67	2.82	2.97	v	230
	h	1200.2	1233.2	1260.7	1286.5	1311.6	1336.3	1361.0	h	
	t	395.6	445.6	495.6	545.6	595.6	645.6	695.6	t	
235	v	1.96	2.14	2.30	2.46	2.62	2.77	2.91	v	235
	h	1200.6	1233.8	1261.4	1287.1	1312.2	1337.0	1361.7	h	
	t	397.4	447.4	497.4	547.4	597.4	647.4	697.4	t	
240	v	1192	2.09	2.26	2.42	2.57	2.71	2.85	v	240
	h	1200.9	1234.3	1261.9	1287.6	1312.8	1337.6	1362.3	h	
	t	399.3	449.3	499.3	549.3	599.3	649.3	699.3	t	
245	v	1.89	2.05	2.22	2.37	2.52	2.66	2.80	v	245
	h	1201.2	1234.8	1262.5	1288.2	1313.3	1338.2	1362.9	h	
	t	401.0	451.0	501.0	551.0	601.0	651.0	701.0	t	
250	v	1.85	2.02	2.17	2.33	2.47	2.61	2.75	v	250
	h	1201.5	1235.4	1263.0	1288.8	1313.9	1338.8	1363.5	h	
	t	402.8	452.8	502.8	552.8	602.8	652.8	702.8	t	
255	v	1.81	1.98	2.14	2.28	2.43	2.56	2.70	v	255
	h	1201.8	1235.9	1263.6	1289.3	1314.5	1339.3	1364.1	h	

t = Temperature, degrees Fahrenheit.
v = Specific volume, in cubic feet, per pound.
h = Total heat from water at 32 degrees, B. t. u.

PIPES

TO DETERMINE THE AREA OF A PIPE IN SQUARE INCHES.—To determine the area of a pipe in square inches, which will deliver a certain number of cubic feet in a definite time, when the velocity of flow is known, the following method may be used: Multiply the quantity of discharge in cubic feet by 144 and divide the product by the velocity of flow multiplied by the time in minutes:

$$\frac{D \times 144}{V \times T} = \text{Area in square inches.}$$

Where D = Discharge in cubic feet.
V = Velocity of flow in feet per minute.
T = Time in minutes.

TO DETERMINE THE VELOCITY OF FLOW.—To determine the velocity of flow in feet per minute for a discharge of a definite number of gallons through a pipe of known diameter in a given number of minutes:

$$V = \frac{D}{G \times T}$$

Where D = Discharge in gallons.
G = Number of gallons per lineal foot.
T = Time in minutes.

TO DETERMINE THE VELOCITY OF FLOW IN FEET PER MINUTE FOR A PIPE TO DISCHARGE A DEFINITE NUMBER OF CUBIC FEET.—To determine the velocity of flow in feet per minute in a pipe of known diameter to discharge a given number of cubic feet:

$$V = \frac{F}{A \times T}$$

or

$$V = \frac{F \times 144}{N \times T}$$

Where F = Number of cubic feet.
A = Area of pipe in square feet.
T = Time in minutes.
N = Area of pipe in square inches.

TO DETERMINE THE APPROXIMATE DIAMETER OF A PIPE.—To determine the approximate diameter of a pipe which will deliver a given number of gallons in a definite number of minutes, the velocity being known:

$$\text{Gallons per foot} = \frac{D}{T \times V}$$

Where D = Discharge per minute.
T = Time in minutes.
V = Velocity of feet per minute.

Refer the result to pipe tables for the nearest diameter giving these gallons per foot.

RELATIVE CARRYING CAPACITY OF PIPES OF VARIOUS DIAMETERS

Diam.	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	11	12
1	1.00	.48	.27	.14	.07	.05	....	....	....	....	....	....	....	....	..	....	....
1¼	2.10	1.00	.55	.29	.16	.10	.06	....	....	....	....	....	....	....	....	....	....
1½	3.70	1.80	1.00	.53	.29	.18	.11	.08	....	....	....	....	....	....	....	....	....
2	7.14	3.40	1.90	1.00	.53	.33	.21	.14	.10	....	....	....	....	....	....	....	....
2½	13.40	6.30	3.50	1.90	1.00	.63	.40	.27	.20	.15	....	....	....	....	....	....	....
3	21.40	10.30	5.70	3.00	1.60	1.00	.67	.43	.32	.23	.15	....	....	....	....	....	....
3½	.....	16.10	9.00	4.70	2.50	1.50	1.00	.68	.50	.38	.23	.15	....	....	....	....	....
4	.....	.....	13.10	6.90	3.70	2.30	1.40	1.00	.71	.56	.34	.23	.15	....	....	....	....
4½	.....	.....	.....	9.60	5.00	3.10	2.00	1.40	1.00	.77	.47	.31	.21	.14	.12	....	....
5	.....	.....	.....	....	6.70	4.40	2.60	1.80	1.30	1.00	.63	.42	.28	.20	.16	.13	.10
6	.....	.....	.....	....	....	6.50	4.30	2.90	2.10	1.60	1.00	.66	.45	.33	.26	.21	.16
7	.....	.....	.....	....	....	....	6.50	4.40	3.20	2.40	1.50	1.00	.71	.53	.40	.32	.24
8	.....	.....	.....	....	....	....	....	6.50	4.70	3.50	2.20	1.40	1.00	.76	.59	.47	.36
9	.....	.....	.....	....	....	....	....	....	6.42	4.77	2.98	1.90	1.33	1.00	.79	.60	.48
10	.....	.....	.....	....	....	....	....	....	8.30	6.30	3.90	2.50	1.70	1.28	1.00	.78	.61
11	.....	.....	.....	....	....	....	....	....	....	8.24	5.02	3.25	2.20	1.66	1.28	1.00	.79
12	.....	.....	.....	....	....	....	....	....	....	10.30	6.30	4.10	2.80	2.08	1.60	1.27	1.00

HEATING OR COOLING SURFACE OF PIPES AND TUBES PER FOOT AND PER INCH OF LENGTH

Diameter	Per Foot	Per Inch
Inches	Square Feet	Square Feet
1⅛	.3272	.0272
1⅜	.3599	.0299
1½	.3927	.0327
1⅝	.4254	.0354
1¾	.4580	.0381
1⅞	.4908	.0409
2	.5236	.0436
2⅛	.5562	.0463
2¼	.5890	.0490
2⅜	.6218	.0518
2½	.6545	.0545
2⅝	.6872	.0572
2¾	.7199	.0599
3	.7854	.0655
3¼	.8508	.0709
3½	.9163	.0763
3¾	.9817	.0818
4	1.0472	.0872
4¼	1.1126	.0927
4½	1.1781	.0981
4¾	1.2435	.1036
5	1.3090	.1090
5¼	1.3745	.1140
5⅜	1.4072	.1173
5½	1.4390	.1200
5¾	1.5053	.1250
6	1.5708	.1309

STANDARD SIZES OF WROUGHT-IRON PIPE

Size of pipe	Actual outside diameter (inches)	Actual inside diameter (inches)	External circumference (inches)	Length of pipe per square foot of outside surface (feet)	Weight per foot of length (pounds)	Number of threads per inch of screw
⅛"	0.405	0.270	1.272	9.434	0.243	27
¼"	0.540	0.364	1.699	7.075	0.422	18
⅜"	0.675	0.494	2.120	5.660	0.561	18
½"	0.840	0.623	2.639	4.547	0.845	14
¾"	1.050	0.824	3.299	3.637	1.126	14
1"	1.315	1.048	4.131	2.904	1.670	11½
1¼"	1.660	1.380	5.215	2.301	2.258	11½
1½"	1.900	1.611	5.969	2.010	2.694	11½
2"	2.375	2.067	7.461	1.608	3.667	11½
2½"	2.875	2.468	9.032	1.328	5.773	8
3"	3.500	3.067	10.996	1.091	7.547	8
3½"	4.000	3.548	12.566	0.955	9.055	8
4"	4.500	4.026	14.137	0.849	10.728	8
4½"	5.000	4.508	15.708	0.764	12.492	8
5"	5.563	5.045	17.477	0.686	14.564	8
6"	6.625	6.065	20.813	0.576	18.767	8
7"	7.625	7.023	23.954	0.501	23.410	8
8"	8.625	7.982	27.096	0.443	28.347	8

Doubling diameter increases pipe capacity four times. The friction of liquids carried in pipes increases as the square of the velocity.

STEAM ENGINES AND STEAM TURBINES

SLIDE-VALVE STEAM ENGINES

The cylinder valves of slide-valve steam engines may be plane blocks sliding back and forth upon plane seats, or the valve seat may be a segment of a cylinder or a cone, which fits a corresponding surface of the valve, steam tight.

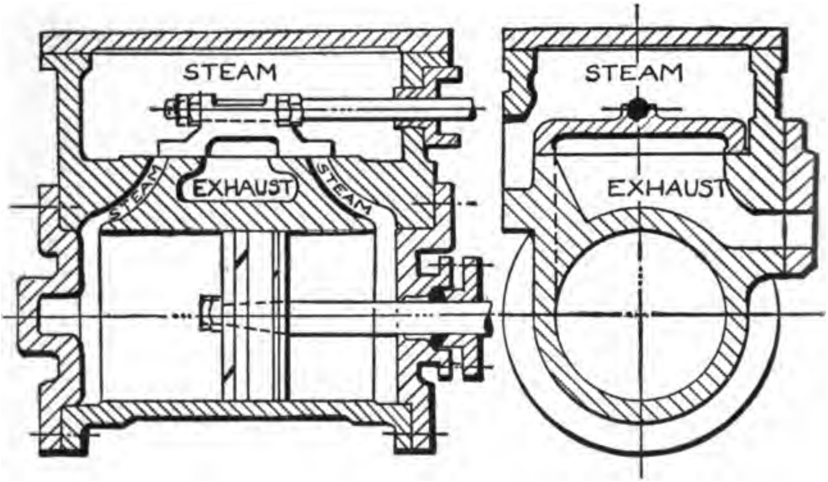


FIG. 1. SEC. 3.—Sectional view of plain slide-valve engine, showing the cylinder and valve-chest.

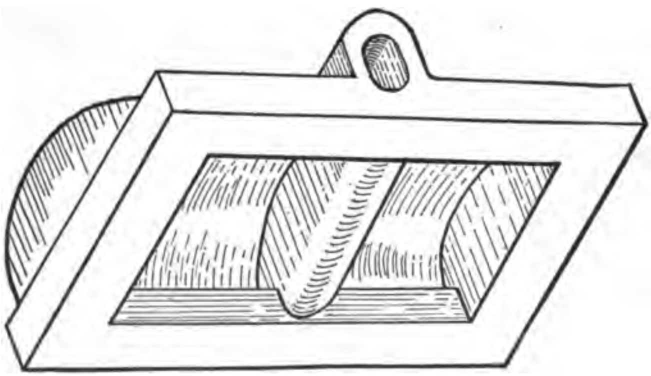


FIG. 2. SEC. 3.—Plain "D" slide valve.

Fig. 1, Sec. 3, shows a sectional view of a plain, slide-valve engine cylinder and valve chest.

It is the function of the valve to time the events: admission, cut-off, release, and compression. The valve shown in Fig. 2, Sec. 3, is the ordi-

nary D slide valve. The cut shows its appearance when looking up at it from the position of the valve seat. The flat surfaces which rub upon the valve seat are clearly shown.

The valve derives its motion from the "crank shaft," through the medium of the "eccentric," "eccentric rod," and "valve stem." The part of the eccentric which revolves with the shaft is called the "eccentric sheave," and the bands which are about the eccentric sheave are called the "eccentric straps." The eccentric straps are fastened to the eccentric rod, whose motion is similar to that of the connecting rod. The rotary motion of the eccentric is transferred into a reciprocating motion at the pin *A* (see Fig. 4, Sec. 3). The pin *A* is fastened to a "slider," which works in guides and transfers the motion to the valve stem.

The various parts of the simple valve gear for a plain, slide-valve engine are indicated in Fig. 4, Sec. 3.

CORLISS VALVE ENGINE

Instead of moving back and forth in a straight line, as the ordinary slide valve does, Corliss engine valves move in an angular direction about their axes.

Corliss steam valves are shaped as shown in Fig. 3, Sec. 3. There are four valves in each engine—two steam valves and two exhaust valves.

FIG. 3. SEC. 3.—Corliss steam valve.

The valves extend clear across the cylinder, and are carried in "holes," or valve seats, which are bored from side to side through the cylinder. These "holes" are closed at the back by plates and at the front by castings, called "bonnets." At each end of the valves a short portion is made cylindrical, to act as a bearing for the valve.

Fig. 5, Sec. 3, shows a sectional view of a Corliss engine cylinder and valves.

The valve receives its rocking motion from a "valve spindle," which is equipped with a bearing and a stuffing box in the "valve bonnet." The valve spindles terminate in tongues, which fit into slots across the end of the valves.

Fig. 6, Sec. 3, shows the arrangement of the valve gear. A casting called the "wrist plate" oscillates on an axis. The "wrist plate" is kept in motion by the "eccentric" on the main shaft through the "eccentric rod," or "carrier," and the "reach rod."

Short cranks or exhaust arms are keyed to the stems of the exhaust valves, and are connected to the wrist plate by "exhaust links."

The exhaust valves are in motion all the time.

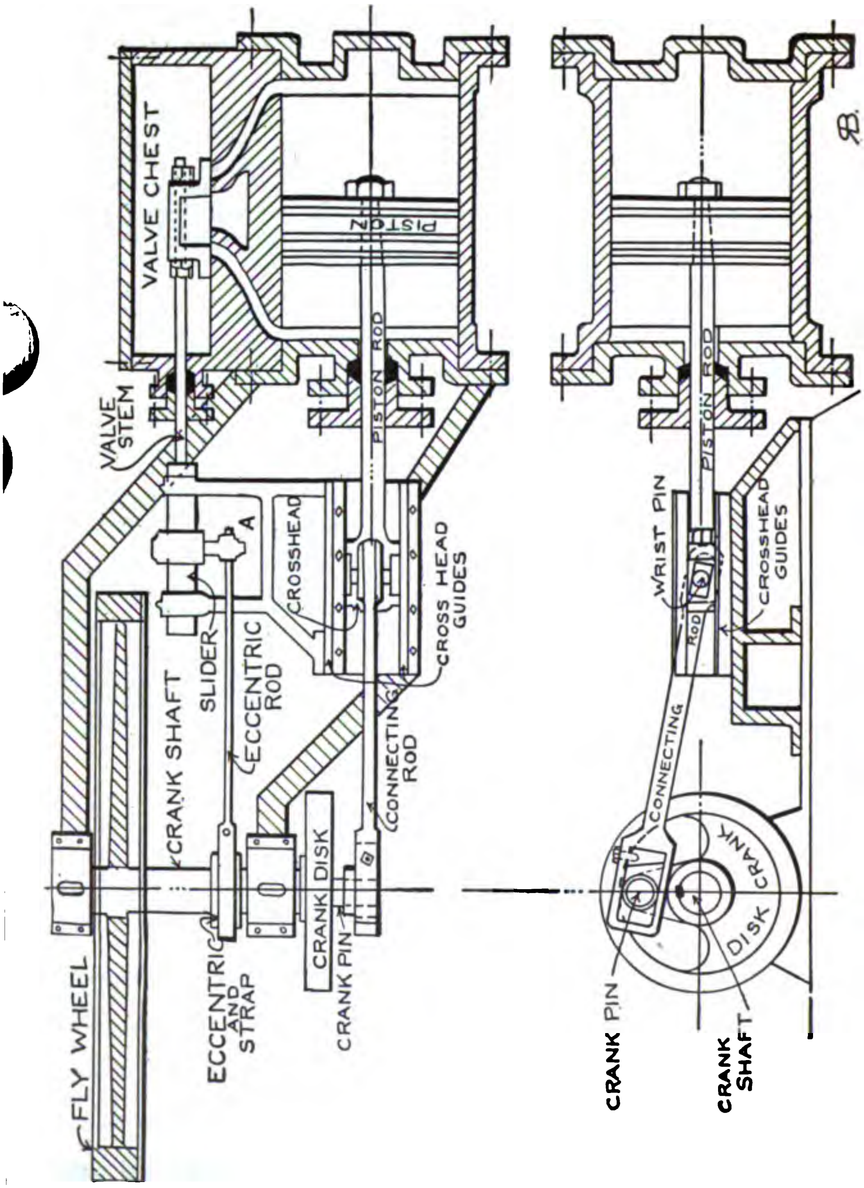


FIG. 4. SEC. 3.—Valve gear of simple slide-valve engine.

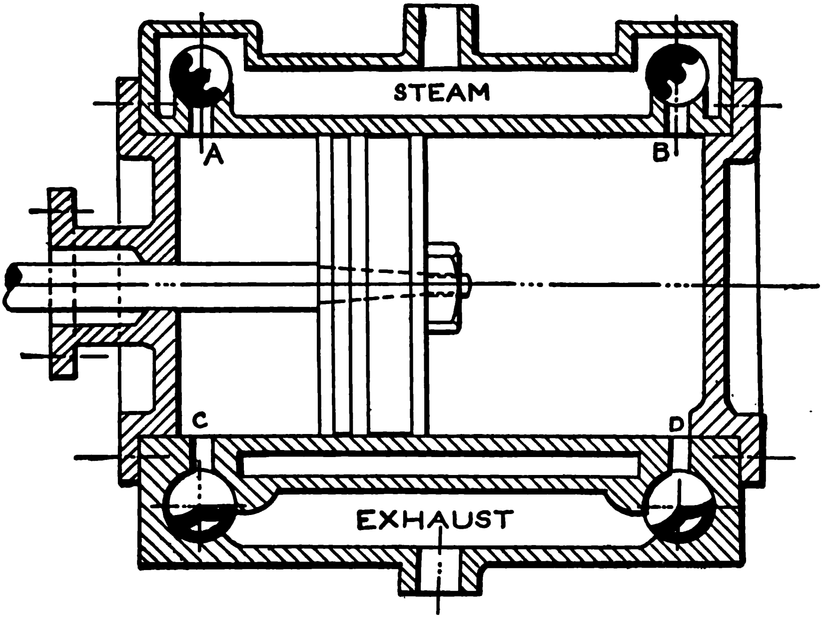
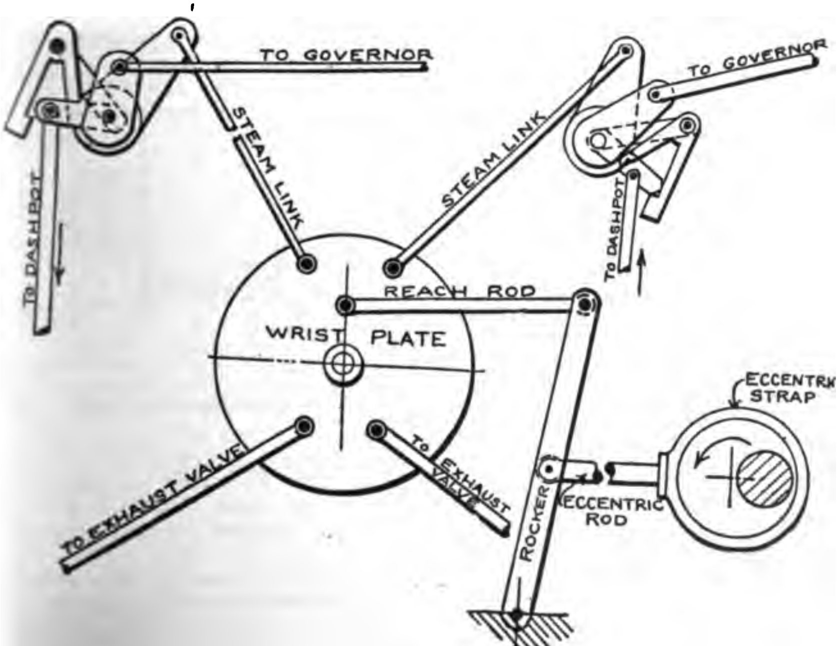


FIG. 5. SEC. 3.—Section through Corliss engine cylinder.



Each valve, as is shown, is a portion of a cylindrical surface. These valves are oscillated or rocked about their axes, to open and close the ports. *A* and *B* are steam ports, and *C* and *D* are exhaust ports. (Fig. 5, Sec. 3).

The steam valves are oscillated by the wrist plate, through the medium of the "steam links." The steam links are not directly connected to the valves, as in the case of the exhaust links, but are connected through special releasing devices. The releasing devices pull the steam valves open at the proper time and then suddenly let go, and the valves are quickly pulled shut by means of the "dash pot rods" and "dash pots."

"Dash pots" are simply pistons, working in cylinders, which have one end closed. As the pistons are pulled up, during the opening of the steam valves, by the rods connecting them to the "releasing gear," a partial vacuum is formed under the pistons, which quickly pulls the rods down and the steam valves closed on release.

PISTON VALVE ENGINES

A "piston valve" is a slide valve, but differs from the plain type of slide valve in that instead of sliding on a plane surface, the valve and valve seat are cylindrical. The "ports" are spread out around the valve so that steam is admitted or exhausted practically around the entire valve. Fig. 7, Sec. 3, shows a simple form of piston valve.

BALANCED VALVES.—A plain "D slide valve" has the full force of the steam pressure on its outer surface, while its inner surfaces are either in contact with the seat or are subjected only to exhaust pressure. The result is an unbalanced pressure, producing a heavy friction load upon the valve gear. Piston valves relieve this condition by keeping constant the pressure all about their circumference.

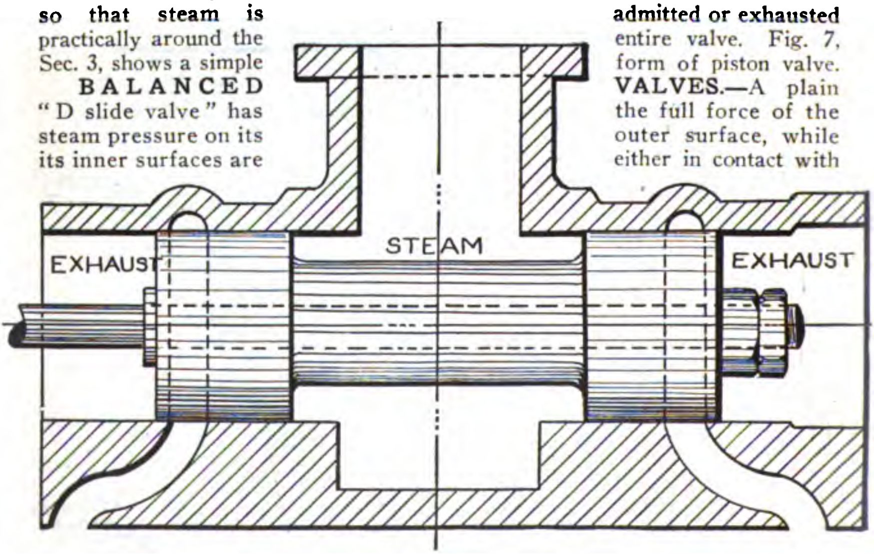


Fig. 7. Sec. 3.—Piston valve.

Leakage is usually greater with the piston valve than the plain slide valve, because of the tendency of the former to wear a non-cylindrical seat.

UNIFLOW ENGINES

The principal differences in the present type of uniflow engines are the arrangements of the valves, valve gear, and methods of adapting the engines to condensing and non-condensing conditions.

Inlet valves may be poppet, Corliss, piston, or slide. They are usually of the poppet type, due to the quick opening and closing features, and also adaptability to high temperatures. The operation of the poppet valves is secured either by cams connected through bell crank levers or straight rods to the eccentric on the main shaft, or directly by cams mounted on auxiliary shafts parallel to the travel of the piston.

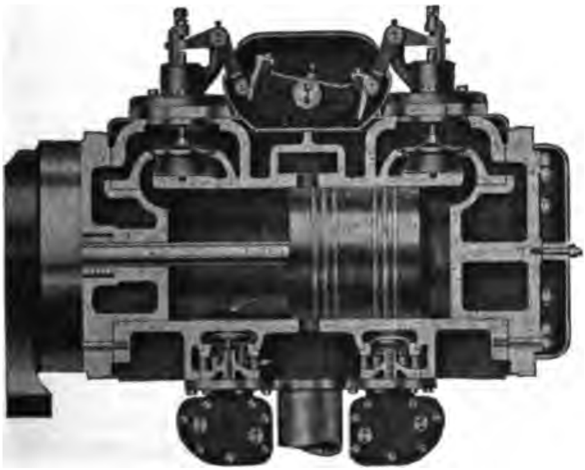


FIG. 8. SEC. 3.—Sectional view of Skinner uniflow engine.

The exhaust steam is usually discharged through a ring of ports which encircle the middle of the cylinder, and which are uncovered by the piston during its travel.

Fig. 8, Sec. 3, shows a sectional view of a Skinner Uniflow engine, and Fig. 9, Sec. 3, shows a view of the gears for the Skinner auxiliary exhaust valves.

Fig. 10, Sec. 3, shows a view of the Nordberg Uniflow engine, fitted with poppet valves. Positive opening and closing of the valves are secured by means of cams operated from eccentrics. The eccentrics are located on a lay shaft, which is geared directly to the main shaft. The steam valves are of the double-beat type.

Fig. 11, Sec. 3, shows the Ames Uniflow engine.

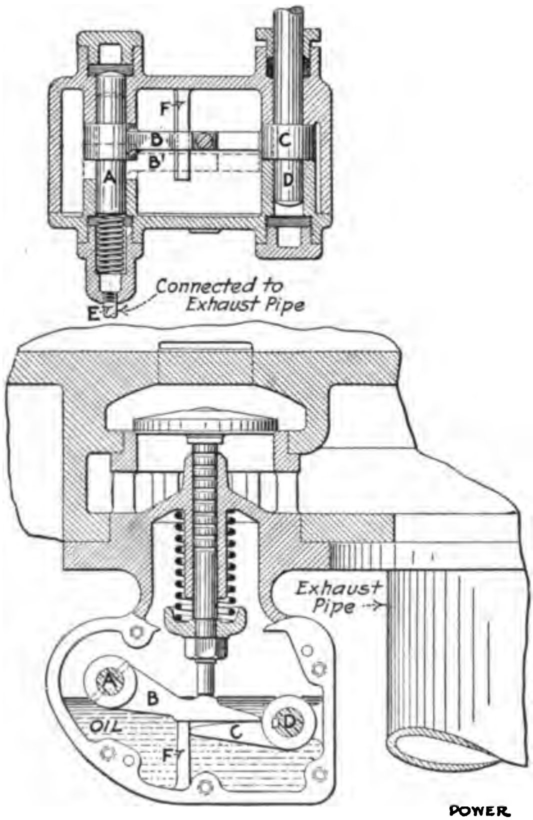


Fig. 9. Sec. 3.—Gear for Skinner auxiliary exhaust valves

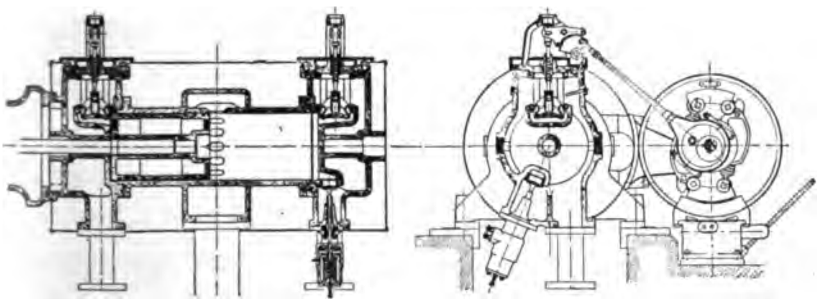


FIG. 10. SEC. 3.—Section of Nordberg uniflow engine.

FIG. 11. SEC. 3.—Section of Ames uniflow engine.

COMPOUND AND TRIPLE EXPANSION ENGINES

The steam may either do all of its work in one cylinder, entering with the exception of the line loss, at boiler pressure and expanding to the exhaust pressure, or it may do part of its work in one cylinder, then exhaust to a second cylinder and do more work, and the process proceed further by exhausting into a third cylinder, etc.

"Simple engines" are those in which the steam expands in one cylinder. "Compound engines" are those in which a second cylinder is supplied with the exhaust of the first, or high-pressure, cylinder.

In a "Cross Compound engine" the high-and low-pressure cylinders are side by side, and each has its own crank on the shaft.

"Tandem Compound" engines are those in which the high- and low-pressure cylinders are in line, both of their pistons being fixed to the same piston rod.

"Angle Compound engines" have their high-pressure cylinder horizontal and their low-pressure cylinder vertical.

"A Triple Expansion engine" allows the steam to expand consecutively in high-pressure, intermediate-pressure, and low-pressure cylinders.

CONDENSING AND NON-CONDENSING ENGINES

When an engine exhausts directly into a "hot well" or to the atmosphere, it is said to be running "non-condensing."

When an engine exhausts into a closed vessel, in which a partial vacuum is maintained, and the steam is condensed by means of cold water, the engine is said to be running "condensing." The closed vessel is called the "condenser." The condensed steam is used as feed water for the boiler.

THE STEAM TURBINE

The steam turbine generally consists of a disk or a cylinder on the circumference of which are a large number of buckets or blades.

Steam is directed at a definite angle against these buckets and causes the disk or cylinder to revolve at high speeds.

There are a number of commercial types of steam turbines on the market, the principal ones being the Westinghouse, Parsons, DeLaval, Curtis, Terry, etc.

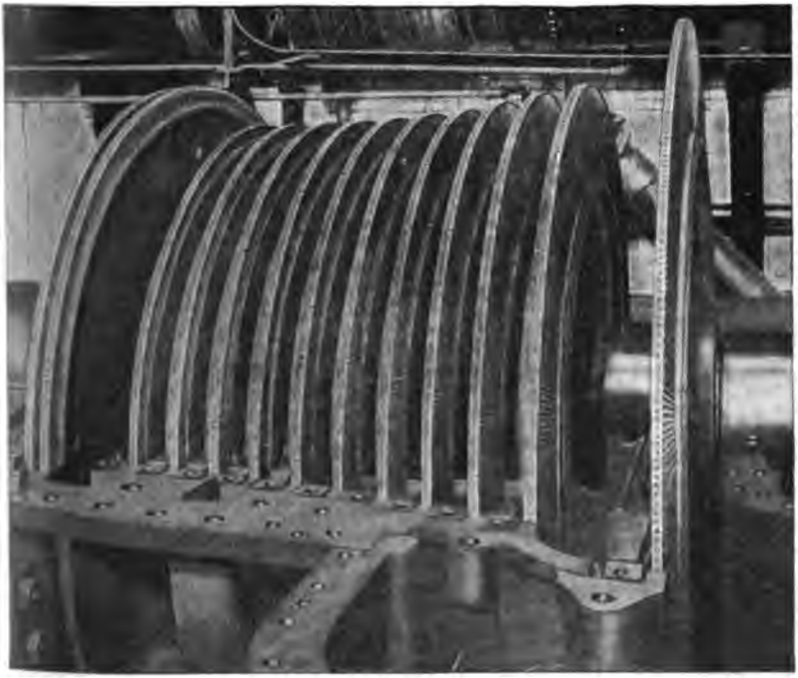
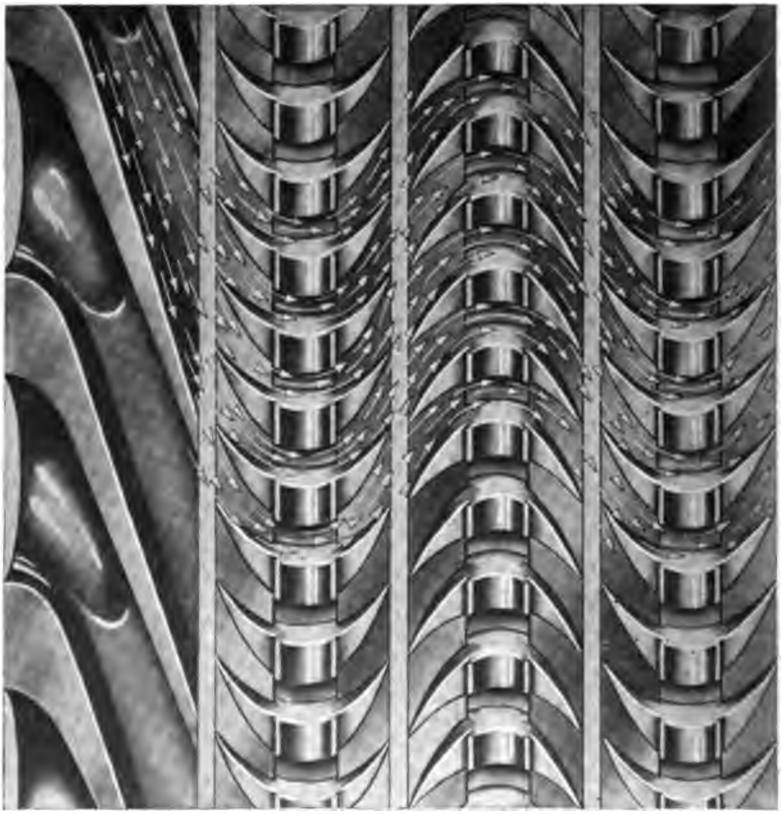


FIG. 12. SEC. 3.—Twelve-stage Curtis steam turbine, with the upper half of the turbine casing removed.

DE LAVAL TURBINES.—In this type of turbine steam enters a chamber surrounding the casing of the turbine, and is directed by several nozzles to the turbine buckets. These buckets are fastened to the outer circumference of a single disk. The steam is directed against the centre line of the bucket at a small angle. The nozzles are tapered, with the large end toward the bucket, so that the expanding steam acquires a high velocity, which it converts into energy by causing the bucket disks to rotate. The revolutions per minute of this type of turbine are high (often 30,000 R. P. M.). The tendency of the rotating element is to rotate about

its gravity axis instead of its geometric, or mechanical, axis. Provision is made to allow the rotating element to adjust its centre of rotation to its centre of gravity. This is accomplished by pumping oil under pressure into the bearings, as a means of providing an elastic cushion.

CURTIS TURBINES.—The Curtis type of steam turbine is an impulse turbine; *i. e.*, the rotating element is actuated by the impact of



Nozzle Revolving Stationary Revolving

FIG. 13. SEC. 3.—Path of steam flow through moving and stationary buckets. (General Electric Co.)

the steam passing through its buckets at relatively high velocity, but without actual expansion in them. Comparatively high initial velocity is given to the steam jet by expansion in a nozzle or set of nozzles. This velocity is absorbed as energy by successive action upon a series of alternately movable and stationary vanes. The steam passes through the buckets of any one "stage" by virtue of its velocity only, there being no

expansion in the stage. The expansion is accomplished in the nozzle passages between the stages. In other words, when the velocity due to the steam expansion in the original nozzles has been absorbed, it is again generated by further expansion in another set of nozzles, whose area is sufficiently greater than the first, to allow for the increase in volume by

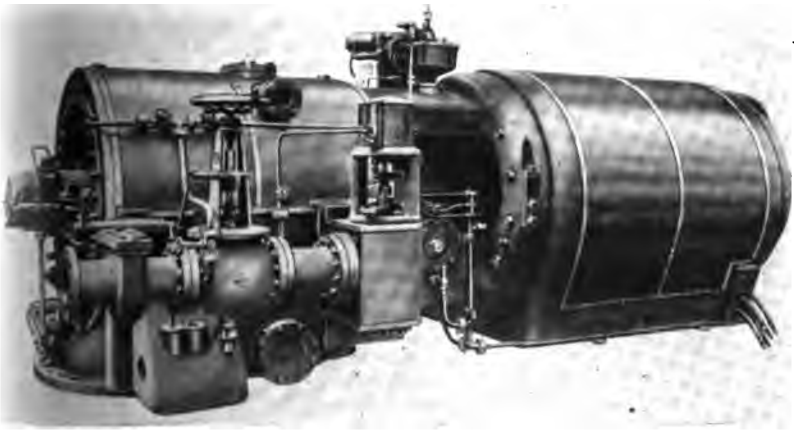


FIG. 14. SEC. 3.—1500 kw. 60-cycle condensing Curtis steam turbine.

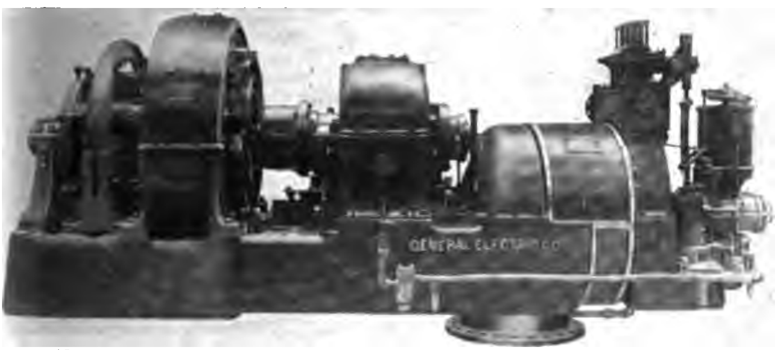


FIG. 15. SEC. 3.—500 kw. Curtis steam turbine geared to direct current generator, 250 volts, 5000/900 R. P. M.

the previous expansion. This operation is repeated upon another larger set of vanes, etc.

Fig. 13, Sec. 3, shows the path of steam flow through the moving and stationary buckets of a Curtis turbine.

Fig. 14, Sec. 3, shows a view of a 1500 k. w. 60 cycle condensing Curtis turbine.

Fig. 15, Sec. 3, shows a 500 k. w. Curtis steam turbine geared to a direct-current generator, 250 volts 5000/900 R. P. M.

Fig. 12, Sec. 3, shows a twelve-stage Curtis turbine, with the upper half of the turbine casing removed, giving a clear view of the interior construction.

For use in driving ship propellers, pumps, direct-current generators requiring large turbines, it is necessary to reduce the shaft speed by means of gears. The gears used with the Curtis machine are flexible. They consist of a double gear built up of flexible plates and so con-

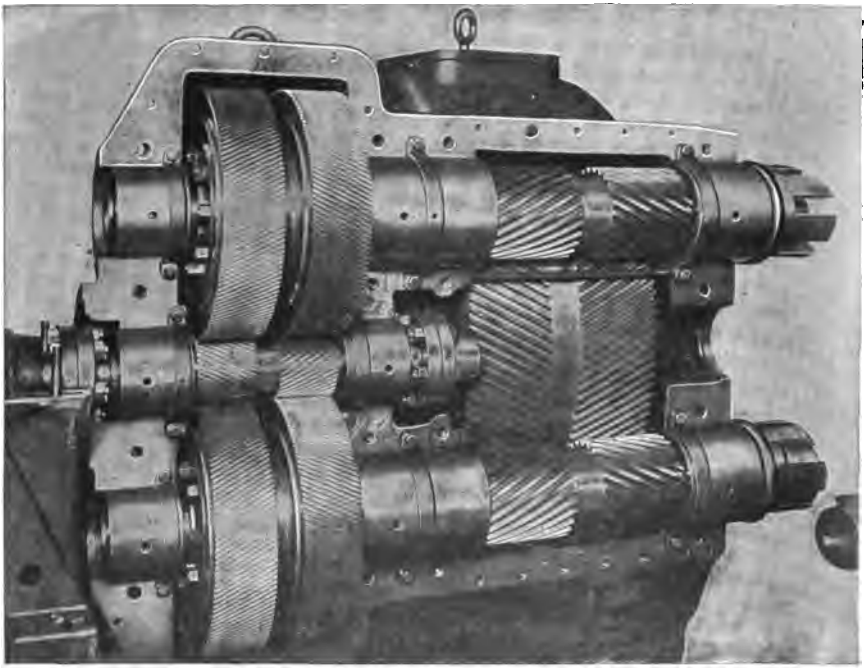


FIG. 16. SEC. 3.—1750 horse-power, 3200/137 revolutions per minute, double-reduction gear, made by the General Electric Company.

structed that if excessive tooth-pressure is exerted by the pinion teeth at any point, a slight axial flexure in the disks will immediately relieve the excessive pressure.

A Curtis double-reduction gear, 1750 horse-power, 3200/137 R. P. M., is shown in Fig. 16, Sec. 3.

WESTINGHOUSE TURBINES.—The original single-flow Parsons type of turbine has been complemented by three Westinghouse variations. The various types are:

(*a*) Single-flow.

(*b*) Semi-double-flow pipe.

(*c*) Double-flow type.

(*d*) Impulse and reaction single-flow type.

The names of these types are descriptive of their operation.

Fig. 17, Sec. 3, illustrates the original single-flow Parsons type of steam turbine. The steam enters the annular ring chamber in the casing

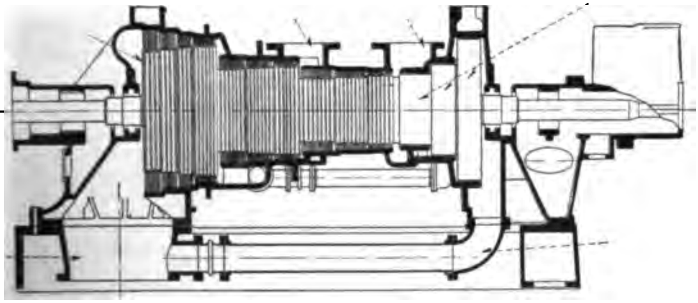


Fig. 17, Sec. 3.—Section of a Parsons type single-flow turbine.

and passes alternately through rings of fixed and movable blades. The length of these blades increases progressively, permitting expansion as the steam passes through the successive rings of blades. When the volume of the steam has increased to the extent that the blades on the small diameter of drum would have to be made too long, the diameters of the drum and casing are increased for the next stage of expansion.

Fig. 18. Sec. 3.—Single-flow rotor, Westinghouse-Parsons turbine.

Fig. 18, Sec. 3, illustrates a single-flow rotor from a Westinghouse-Parsons turbine.

For large turbines an oil relay mechanism, as shown in Fig. 19, Sec. 3, is used to operate the steam valves. The lubricating oil circulating pump maintains a higher pressure than is required for the lubricating system. The governor controls a small relay valve *A*, which allows the high-pressure oil to flow to, or exhaust from, the operating cylinder.

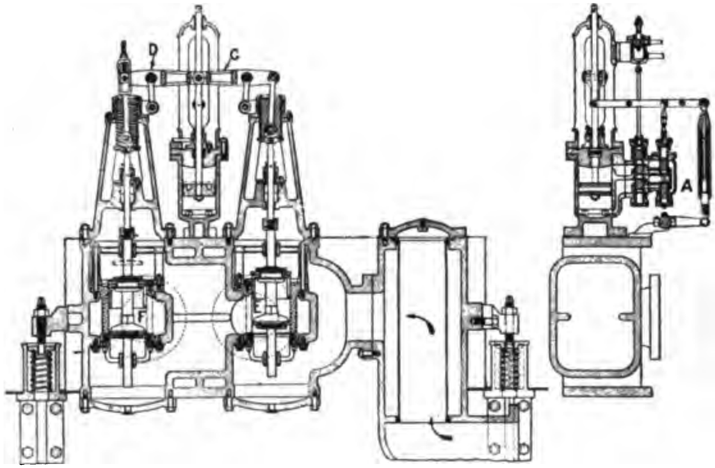


FIG. 19. SEC. 3.—Valve gear with oil relay, Westinghouse turbine.

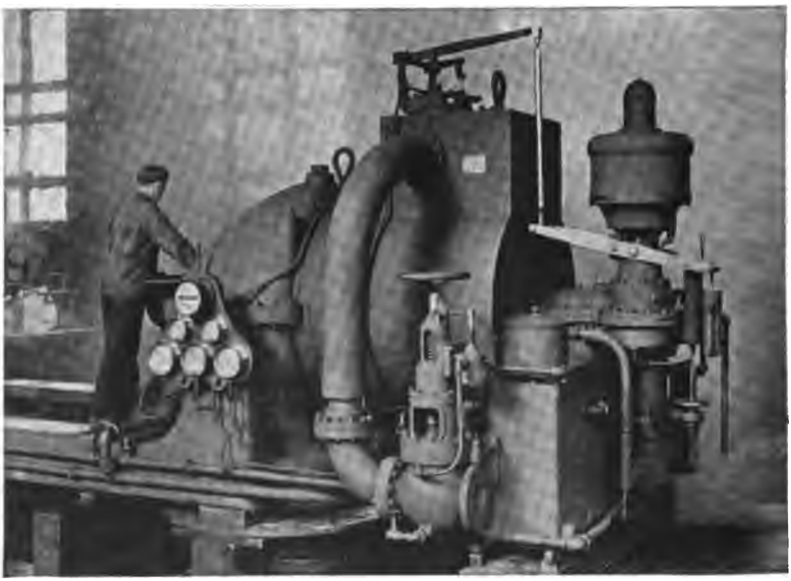


FIG. 20. SEC. 3.—Latest design of Westinghouse turbine.

When oil is admitted to the operating cylinder, the lever D moves simultaneously with C, but, on account of the slotted connection with the stem of the secondary valve F, the latter does not begin to move until the primary valve is raised to the point at which effective opening ceases to be increased by further upward travel.

FIG. 21. SEC. 3.—Rotor of machine in Fig. 20.

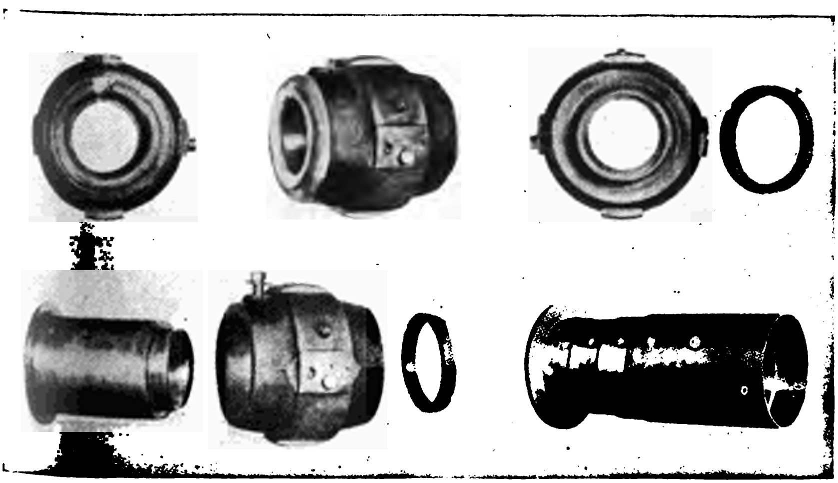


FIG. 22. SEC. 3.—High-speed Westinghouse turbine bearing

Fig. 20, Sec. 3, shows the latest design of Westinghouse turbine, which embodies a combination of the impulse and Parsons types.

Fig. 21, Sec. 3, shows the rotor of this machine.

NOTE. See index for marine installations Westinghouse turbines.

HIGH-SPEED BEARINGS.—The speed of the spindle, running at more than 3000 R. P. M., tends to rotate it on its gravity axis instead of

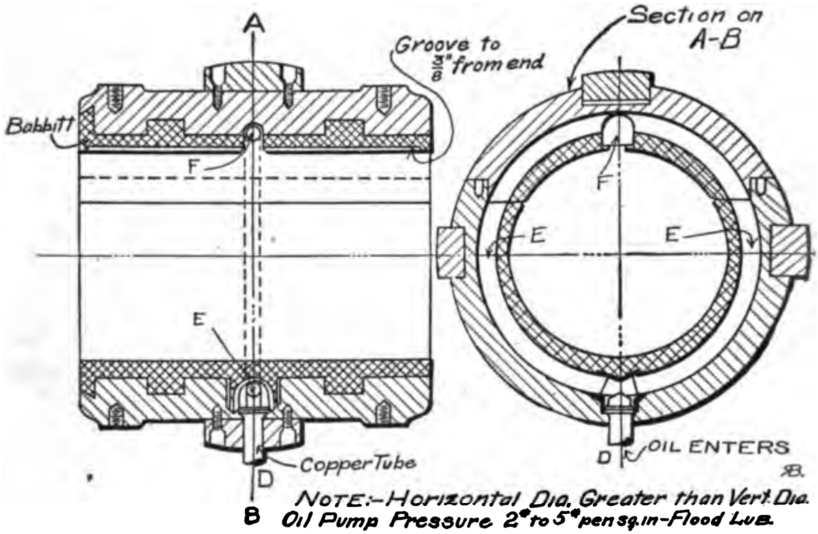


FIG. 23. SEC. 3.—Low-speed turbine bearing.

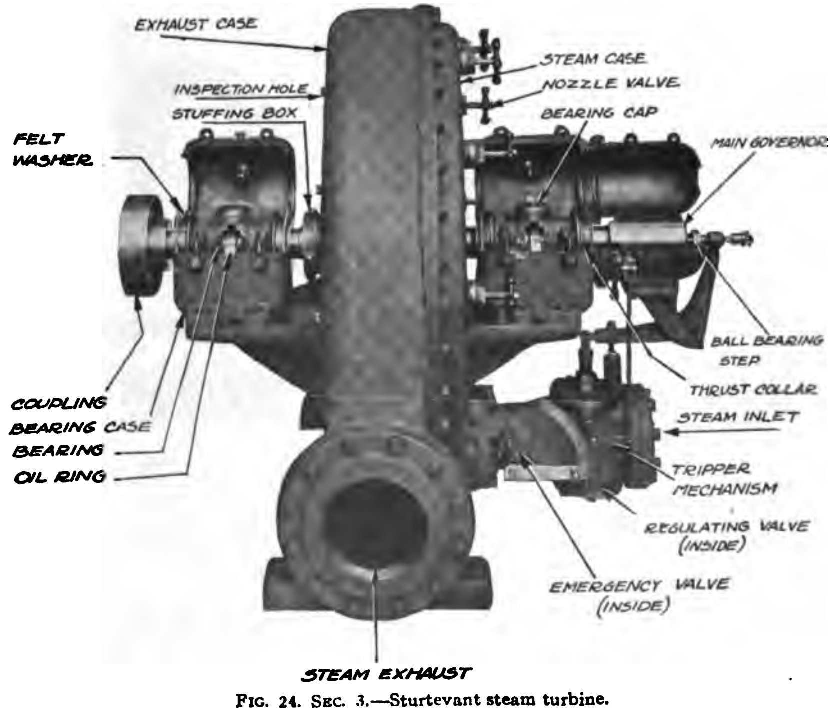


FIG. 24. SEC. 3.—Sturtevant steam turbine.

FIG. 25. SEC. 3.—Channel oiling rings, showing oil scoop. Sturtevant steam turbine.

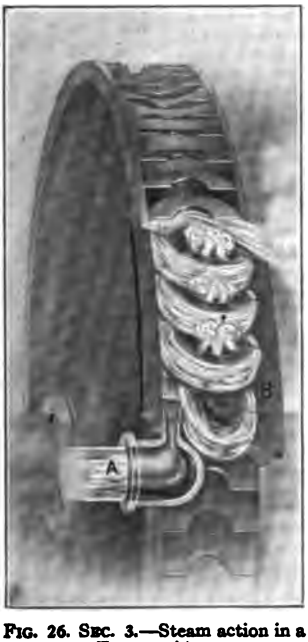


FIG. 26. SEC. 3.—Steam action in a Terry turbine.

its geometric or mechanical axis. This condition might cause disagreeable vibration when the turbine revolves at full speed. To compensate this condition, the Westinghouse Machine Company uses a bearing on high-speed turbines made up of several concentric tubes, having a slight clearance between them. The lubricating oil fills these clearances with an elastic cushion, which makes the bearing flexible.

The tubes are carried in a cast-iron sleeve which rests upon a pedestal. Fig.22, Sec. 3, shows the various parts and the assembled bearing. There

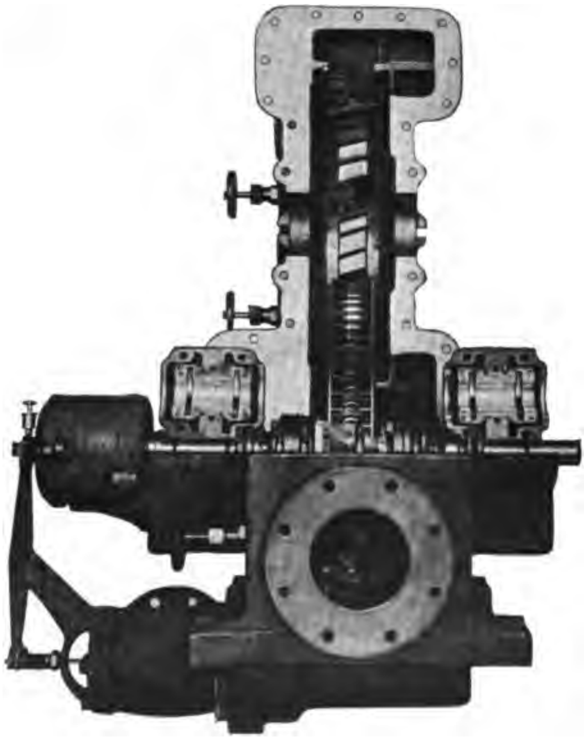


FIG. 27. SEC. 3.—Terry turbine, type G.

are no water-cooled bearings used on the Westinghouse turbo generators, Fig. 23, Sec. 3, shows a form of bearing used for low-speed turbine bearings, where the critical speed is never reached, and there is no need for the concentric ring bearings. A babbitt metal lining is used, and the bearing is made in halves. Before the babbitt metal is run in, a copper tube E is placed in a groove in the shell. The lubricating oil enters at D and flows to the top of the bearing through E and out through F. The groove in the babbitt surface distributes the oil towards the ends of the bearing.

STURTEVANT STEAM TURBINES.—Figs. 24, Sec. 3, and 25, Sec. 3, show the Sturtevant steam turbine and its channel oiling rings. The bearings used in these turbines are split. They are of the spherical type and self-aligning. The special channel-oiling device, shown in the figure, is a part of the equipment. It has been elsewhere described. The

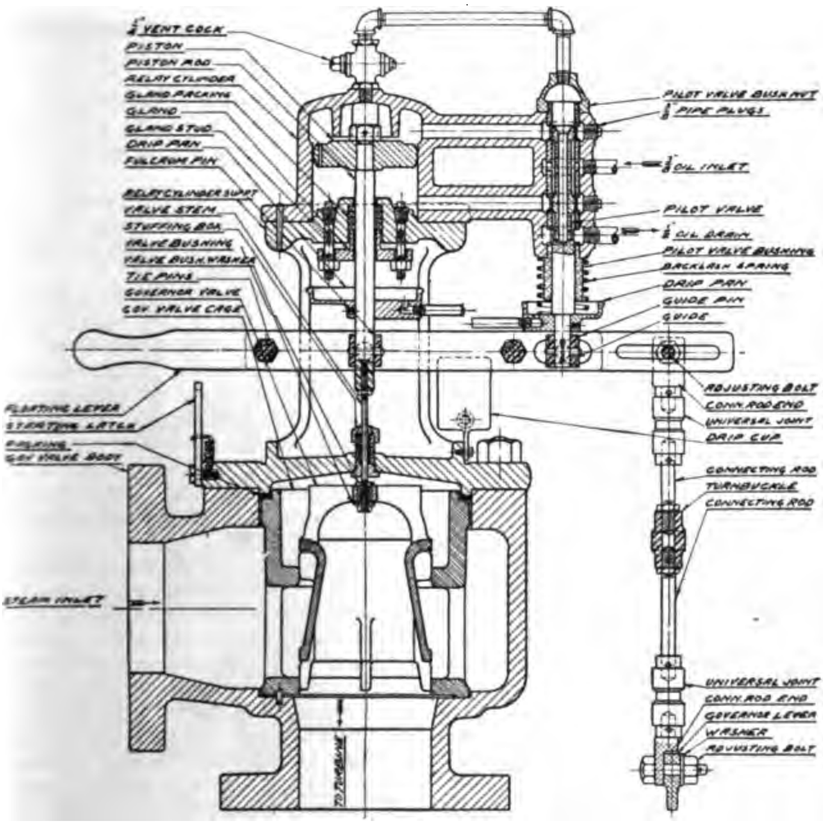


Fig. 28. Sec. 3.—Terry oil relay governor mechanism; Terry turbine.

bearings are lined with a high-grade bearing metal or with phosphor bronze, and the shaft is made of 3 1/2-inch nickel steel, ground to size.

TERRY TURBINE.—Fig. 26, Sec. 3, shows the action of the steam in passing through a Terry steam turbine. The steam enters at *A*, the nozzle, in which it is expanded from boiler pressure to the exhaust pressure, approximately. It issues from the nozzle at a high velocity and strikes one side of the wheel bucket, in which its direction is reversed 180°. As the initial impact absorbs only a portion of the total energy at

B, the jet of steam passes into the reversing chamber, which returns it to the wheel bucket, which action is repeated several times, until all of the available energy is removed.

Fig. 27, Sec. 3, shows a view of the Terry turbine, type G, with its cover raised to show its construction.

The bearings, as can be seen, are split on the centre line, and fitted with two brass oil rings. Oil reservoirs are provided below the bearings. They are designed with water-cooling provisions, in cases of warm locations. At high speeds forced lubrication is used in conjunction with ring oiling in reserve.

THE TERRY OIL RELAY GOVERNOR (TERRY TURBINES). —Fig. 28, Sec. 3, shows the construction of the Terry oil relay governor as usually supplied. The construction may vary slightly in various installations.

An oil relay governor differs from a direct-acting governor in that the oil governor moves a pilot valve only, the main governor valve being moved by an oil piston, which is controlled by the pilot valve. This method allows the governor to take care of any size valve.

The principle of operation is as follows: Oil at 25 to 40 pounds pressure per square inch is supplied at the centre of the pilot valve, and oil-drain connections are provided. When the load is increased, there is momentary drop in the turbine speed, and the governor responds by slightly lowering the connecting rod, which in turn moves the pilot valve downward and admits high-pressure oil below the oil piston. The space above the piston is opened to the drain, thus causing the piston to move upwards and increases the steam valve opening. The floating lever that is attached to the piston rod moves with it and returns the valve to its central position and stops further movement of the steam valve until there is another impulse from the governor.

When the load is decreased, the turbine speed rises, the governor moves the connecting rod and the pilot valve upwards, which admits high-pressure oil above the piston and opens the space below the piston to the drain. The piston, therefore, moves down and acts to shut the steam valve, while the floating lever returns the pilot valve to a central position.

In operation, the steam valve follows the movements of the pilot valve so closely that the pilot valve movement is small, except for a sudden change of load. A small leakage of oil is permitted from under the piston to above it to permit any gas or air to escape, and the vent cock at the top of the cylinder gives a small outlet to the drain. There is always some circulation of oil which is intended to prevent accumulation of gas or air at any point.

THE STEAM ENGINE INDICATOR AND ITS USE

GENERAL CONSTRUCTION.—The steam engine indicator may be described as being a recording pressure gauge, which is designed to be attached to the cylinder of an engine and connected by suitable means to the cross-head, so that a curve may be drawn to scale on a sheet of paper which will represent the pressure within the cylinder at the various parts of the stroke of the piston.

FIG. 29. SEC. 3.—Outside view of Crosby steam engine indicator.

The essential parts of an indicator are as follows: A cylinder, in which is a movable piston, whose movement is resisted by the compression of a calibrated spring. The relative movement of the piston is transferred by a system of small levers to the "pencil arm." The pencil arm carries at its extremity a small piece of writing lead, which may be pressed against the paper carried on the "drum." The drum is made to rotate in a relative motion, with the travel of the piston in the cylinder, by means of an indicator cord, which is attached to a suitable reducing gear, that receives and reduces the motion of the cross-head.

The indicator is connected by a steam passage to the interior of the

engine cylinder. Thus it can be seen that the curve or diagram drawn by the indicator is a record of the pressures in the engine cylinder at the various parts of the piston stroke. Fig. 29, Sec. 3, and Fig. 30, Sec. 3, show an outside and sectional view of the Crosby Outside Spring Indicator.

A typical diagram, obtained by the steam engine indicator from a single-cylinder, slide-valve engine in good condition, is shown in Fig. 31, Sec. 3. The action of the engine valve may be interpreted from the indi-

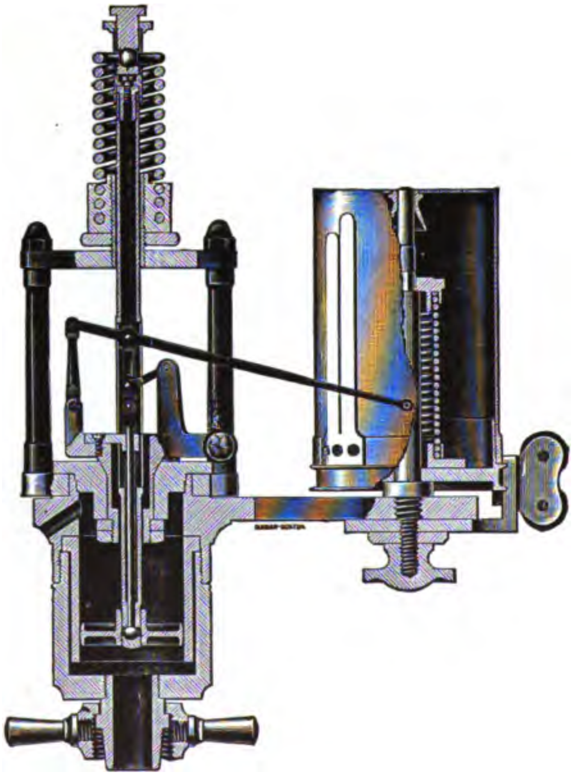


FIG. 30. SEC. 3.—Sectional view of Crosby steam engine indicator.

cator diagram as follows: The steam valve is opened at 6, and the line 6–1 is called the "admission line." From 1–2 the steam valve is open and the piston is moving out on its stroke. At 2 the steam valve is closed; this point is called the "cut-off." The steam is then expanded in the cylinder as the piston moves out. At 5 the exhaust port is opened and the pressure falls; this point is called the "release point."

The line 3–4 is called the "exhaust line" and shows the drop in pressure due to the open exhaust valve. The piston, now having arrived at the end of its stroke, starts back. The line 4–5 is the "back-pressure line."

The piston is now pushing the spent steam out of the exhaust port. At 5 the exhaust port is closed and the steam remaining in the steam cylinder is compressed, acting as a cushion to absorb the inertia of the moving parts. The pressure rises, due to compression, until the point 6 is reached, when steam is again admitted to this end of the cylinder by the uncovering of the steam port by the valve. The cycle of events is then repeated for this end of the cylinder.

The cycle of events just described occurs alternately in both ends of the cylinder. These ends are called the "head" and "crank" ends, respectively. There will be a separate card for each end of the cylinder. These cards are usually taken on the same sheet of paper, so that the record will be complete on one sheet. The line O–X is the "vacuum line" and is drawn to scale, 14.7 degrees below the atmospheric line.

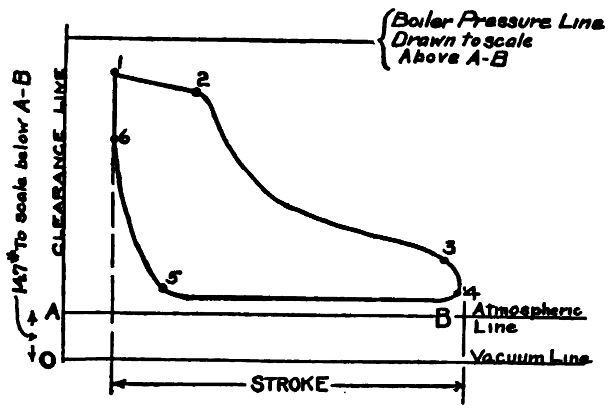


FIG. 31. SEC. 3.—Typical indicator diagram.

MEAN EFFECTIVE PRESSURE.—It should be evident, that if the mean height of the indicator diagram in hundredths of an inch is obtained, and the "scale of the spring," which is the number of pounds required to compress the spring one inch, is known, the mean effective pressure developed during that stroke can be obtained. For the head end of the cylinder this "mean effective pressure" per square inch, multiplied by the area of the piston in square inches, will give the total force acting on the piston at that end during that stroke. For the crank end of the cylinder a reduction of the effective area of the piston is produced by the area absorbed by the piston rod; therefore, the area of the piston in square inches, minus the area (cross-section) of the piston rod, multiplied by the mean effective pressure for that end, will give the total force acting on the piston at that end for that stroke.

By multiplying the mean value of the crank end and the head end total forces by the number of feet travelled by the piston per minute, the foot-pounds of work done per minute are obtained.

HORSE-POWER

"**HORSE-POWER**" is the rate of doing work at 33,000 foot-pounds per minute. Therefore, if:

P = Mean effective pressure, = mean height diagram (inches) × spring scale.
A = Area of the piston (effective) in square inches.
S = Speed of the piston in feet per minute.

Then the horse-power developed by a single cylinder engine will be:

$$\text{H. P.} = \frac{P \times A \times S}{33{,}000} \quad \text{or:} \quad \text{H. P.} = \frac{P \times L \times A \times N}{33{,}000};$$

where P = M. E. P.
L = Length of stroke in feet.
A = Effective area of piston in square inches.
N = Number of strokes per minute, which is twice the number of R. P. M.

INDICATED HORSE-POWER.—The horse-power obtained with the aid of the indicator is called the Indicated Horse-power of the engine. (I. H. P.)

BRAKE HORSE-POWER.—To obtain the power output at the fly-wheel of the engine, the Brake Horse-power must be determined. (B. H. P.)

MECHANICAL EFFICIENCY.—The mechanical efficiency of an engine is the ratio $\frac{B.H.P.}{I.H.P.}$.

METHODS OF OBTAINING THE BRAKE HORSE-POWER.—The brake horse-power of an engine is the rate of delivery of energy from the fly-wheel of the engine. It is measured by means of a dynamometer, which may be one of several types.

The most common form of dynamometer is the Prony Brake.

The form of a typical Prony Brake is shown in Fig. 32, Sec. 3. The operation of this apparatus is as follows: H is the fly-wheel of the engine, turning as indicated by the arrow. The lever A rests on the wheel H as shown. K and L are wooden blocks, which are pressed against the face of the fly-wheel by the tension produced by the adjustable strap B and the weight of the yoke O, thus applying a friction load to the fly-wheel as desired. The pressure, due to the energy absorbed by the brake, is carried by the lever A and the post P to the platform scales S, which are adjusted to just balance the load.

If R = Length of the brake arm or lever R in feet.
N = Revolutions per minute of the fly-wheel.
W = Weight in pounds at distance R, as measured by the scales S.

Then the brake horse-power would be: $\frac{2\pi RNW}{33{,}000}$

$2\pi R$ is the circumference of the circle that would be travelled by the end of the brake lever if it could turn. π is 3.1416.

The value $\frac{33{,}000}{2\pi R}$ is called the "brake constant" and is the same for all loads when using the same brake.

Before starting the run, a "zero reading" of the brake must be taken, since the scales weigh not only the pressure due to the friction load on the lever, but also the weights of the brake and post *P*. These weights must be determined and subtracted from all of the readings of the scales during the test, to obtain the net weights.

To determine the zero reading, the strap *B* is loosened and the fly-wheel is turned by hand in one direction and the weight registered on the

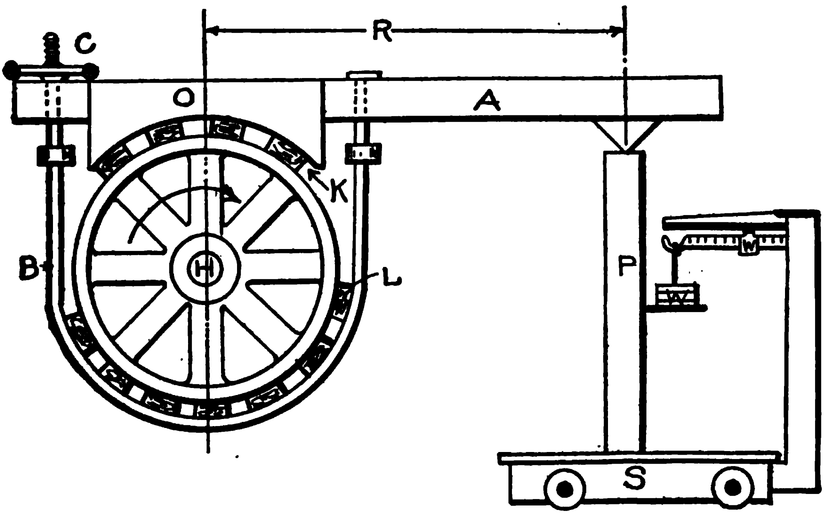


FIG. 32. SEC. 3.—Outline drawing of a Prony brake.

scales is noted. Then the fly-wheel is turned in the opposite direction and the weight registered by the scales is again noted. The friction between the loosened brake band and the fly-wheel is assumed to be the same for either direction of fly-wheel rotation. In one case, therefore, the friction load of the brake itself is added to the combined weight of the brake lever and post, while, when the direction of the rotation is reversed, the friction load is deducted from the weight of the lever and post. By adding these two weight readings together, and dividing the result by two, the mean weight of that part of the prony brake which rests upon the scales is determined. This value is called "the brake zero."

FRICTION TESTS WITH THE ENGINE INDICATOR

As a means of illustrating a typical method of using the steam engine indicator to demonstrate the relative efficiencies of two shafting oils, the following assumed conditions are used, and the test is written up in the approved form:

Report of Friction Test

DATE (3-1-16). MADE AT (ROYAL MFG. CO.)
BY (C. J. BROWN). RESULTS CHECKED BY (J. B. SMITH, PLANT ENGINEER).

PURPOSE OF TEST.—To compare the relative efficiencies and economies of two shafting oils, designated as Oil No. 1 and Oil No. 2.

Oil No. 1 costing .... 18 cents per gallon
Oil No. 2 costing .... 16 cents per gallon

OPERATION.—The mill was operated with all shafting running and with all machines "thrown off." No. 2 oil was supplied to all of the cups and feeds in just sufficient quantities to keep the bearings normally cool.

When the conditions were normal, a series of indicator cards were taken. When these cards were measured, it was found that the engine was developing 210 H. P. at 100 R. P. M.

The shafting was now stopped and the bearings were flushed out with kerosene, so that none of them contained any residue of oil No. 2.

Oil No. 1 was now placed in the oil cups and the shafting and engine were operated at as near the same running conditions as those which prevailed during test No. 2 as it was possible to obtain.

A series of indicator cards were taken, and, when measured, showed that, when using oil No. 1, the power developed by the engine when making 100 R. P. M. was 203 H. P.

It was estimated that in this plant the cost of an indicated horsepower per year was $35.

The oils were given a quantity test, by lubricating the shafting bearings with each oil for a period of one week, using just enough oil to keep the bearings running cool. The results of this test were as follows:

112.3 gallons of oil No. 2 and 96.5 gallons of oil No. 1 were required per week.

SUMMARY OF THE TEST.—

Cost of Oil No. 2:

112.3 × 16 = $17.97 per week. 17.97 × 52 = $934.44 per year. (210 — 203 × 35.00 = $245.00 (cost of the excess friction load).

Total Cost of Lubrication Using Oil No. 2: $245.00 per year
934.44 per year

$1179.44

Cost of Oil No. 1:

96.5 × 18 = $17.37 per week. 17.37 × 52 = $903.24 per year. Deducting the cost of the (7) horse-power saved per year and valued at $245.00—

Total cost of lubrication, using oil No. 1	$903.24
	245.00
	$658.24
The saving when using oil No. 1 is	$1179.44
	658.24
	$521.20

NOTE. This amount seems to be large to those who have not come into contact with tests such as the one outlined above, but the author can assure the reader that this is a very conservative result, and that similar scientific tests conducted in the average mill will produce even more surprising results.

CYLINDER FRICTION TESTS WITH THE INDICATOR

A typical test to compare the efficiencies and economies of two cylinder oils is outlined as follows, assumed values being used as a method of demonstration. The following outline is the proper form in which these tests should be written up:

Friction Test

DATE, 4-10-16. MADE AT AJAX LOCOMOTIVE CO.
BY H. B. JONES. CHECKED BY B. B. BROWN, PLANT ENGINEER.

PURPOSE OF TEST.—To compare the relative efficiencies and economies of two cylinder oils, designated as oil *A* and oil *B*, oil *B* being in present use:

Oil *A* costing .... 35 cents per gallon
Oil *B* costing .... 33 cents per gallon

CONDITIONS.—The engine is a slide-valve type, direct connected to a dynamo. The normal running speed is 130 R. P. M. The bearings of the engine are flood-lubricated, and those of the dynamo are ring-fed.

OPERATION.—The engine was run at full normal speed, with dynamo carrying no load.

Cylinder oil *B* was fed to the cylinder at the rate of five drops per minute, which had been found to be the minimum feed for this oil to prevent signs of distress in the cylinder.

A series of indicator cards was taken, which, when measured, showed that the engine was developing 23.5 H. P.

The engine was run for three hours with no cylinder oil, and at the expiration of this time the lubricator was emptied of oil *B* and oil *A* was substituted.

The running conditions were again maintained as near as possible to those prevailing when testing oil *B*.

After running with oil *A* for one hour, to permit a film of this oil to become thoroughly spread over the surfaces of the cylinder and valve,

and feeding five drops of oil per minute, a second series of indicator cards was taken. When these cards were measured it was found that the horse-power developed was 18.

The feed of oil *A* was now reduced until the cylinder showed signs of distress, when the feed was increased until the conditions returned to normal. It was found that normal running conditions could be maintained when feeding four drops of oil *A* per minute. A series of indicator cards was taken and showed that the horse-power developed had not been increased by the reduced feed, but remained at 18.

SUMMARY OF TEST.—

Oil *B* fed at five drops	23.5 H. P.
Oil *A* fed at four drops	18.0 H. P.
	5.5 H. P.

Oil *A* fed at four drops per minute saved one drop per minute over the consumption of oil *B*. Therefore:

$60 \times 24 = 1440$ drops per day. Assuming 4500 drops of oil to the quart, which is a conservative figure, and four quarts to the gallon, $\frac{1440 \times 365}{4500 \times 4} = 29.2$ gallons saved per year, using oil *A*.

Total Cost of Lubrication, Using Oil B:

Three and one-half barrels of oil *B* used in the past per year would be: $3.5 \times 50 \times 33 = \$57.75$, cost of oil *B*.

Five and one-half excess friction horse-power will cost: Assuming \$50 per horse-power per year, which value includes fuel, attendance, fixed charges, depreciation, etc.:

$$5.5 \times 50 = \$275.00 \text{ per year.}$$

Therefore the total cost of lubricating with oil *B* will be:

$$\begin{array}{r} \$57.75 \\ \$275.00 \\ \hline \$332.75 \end{array}$$

Total Cost Lubrication, Using Oil A:

Deducting the saving in gallonage.

$$(3.5 \times 50) - 29.2) \times 35 \text{ cents} = \$51.03.$$

Subtracting cost of oils, and adding cost of friction H. P., $\$57.75 - \$51.03 + \$275.00 = \$281.72$, saved in one year by using oil *A*, even at an increased price of two cents per gallon, over the cost of yearly lubrication using oil *B*.

THE VALUE OF TESTS.—It is not uncommon to find conditions similar to those described in the cylinder oil test preceding. Oil engineers, working in conjunction with the operating engineer, can produce some very interesting results by similar tests. It will be surprising to the operating engineer, who thought that his engine cylinders were receiving efficient lubrication because there was no apparent sign of cylinder cutting or distress, to learn how much money may be saved in operating cost by scientific lubrication.

INDICATOR NOTES

NOTES ON THE USE OF THE INDICATOR.—The following general suggestions should be followed in connection with attaching and using the indicator.

(*a*) The indicator should be attached as closely to the cylinder as is practical. (This is especially necessary with regard to high-speed engines.)

(*b*) If possible, the indicator should be attached direct to the cylinder by means of a valve tapped into the cylinder, and if connecting pipes must be used, they should have a diameter not less than 1/2-inch and should be as free from bends as possible.

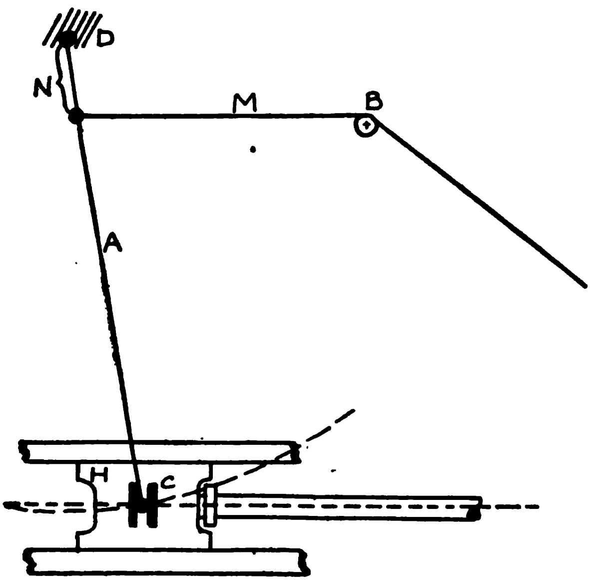


FIG. 33. SEC. 3.—Reducing rig.

(*c*) A three-way cock, attached midway in a line of pipe with connecting holes at either end of the cylinder, makes a good arrangement. Diagrams can be taken alternately from either end of the cylinder by simply turning the valve.

(*d*) Steam cylinders are usually drilled and tapped, and have plugs screwed into the tapped holes for taking the indicator connections.

(*e*) The holes drilled into the cylinder for indicator connections must enter the cylinder in the clearance space, so that the piston will not travel over them.

(*f*) In order to reduce the movement of the cross-head of the engine to the length of the indicator card to be taken, several devices are in use. The reduced motion obtained with these devices must be in direct ratio to the speed of motion of the piston in order to get correct cards.

The following descriptions cover some of the most common forms of rigs for reducing the crosshead motion:

(1)

Fig. 33, Sec. 3, shows the general arrangement of a reducing lever, which is adapted for large and quick-running engines. Referring to the letters in the figure, *D* is a fixed point, *C* is a steel stud, held fast in the lever *A*, but having a "T"-headed top, loosely held in a slotted plate, which is attached to the centre of the crosshead *H*, thus permitting the lever to swing in such a manner that its lower end travels a distance equal to the full swing of the crosshead travel.

In order to determine the distance *N*, which is the radius of swing of the point, to which is attached the indicator cord *M*, so as to give the desired length of indicator card, use the following rule:

Let *X* equal the length of the lever *A* (inches).

Let *Y* equal the length of the engine piston stroke (inches).

Then:

$\frac{X}{Y}$ (×) the desired length of diagram in inches = radius *N* in inches.

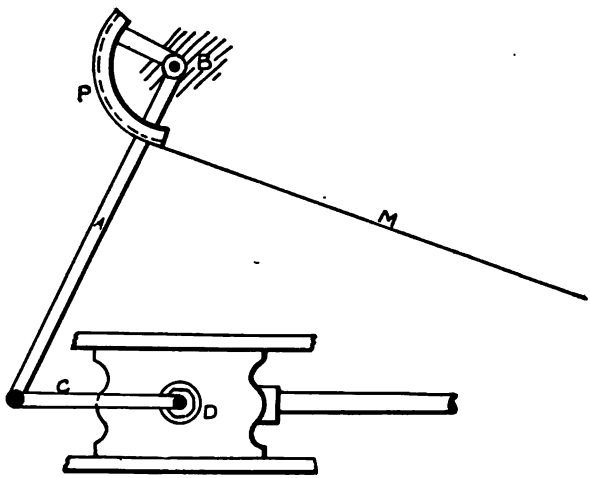


Fig. 34. Sec. 3.—"Brumbo pulley" reducing rig.

(2)

Fig. 34, Sec. 3, shows a type of reducing rig known as the "Brumbo pulley." This motion is in very common usage. *B* is a fixed point, *A* is a lever of straight-grained pine, swung from fixed point *B*, *C* is a link, having a length of from 1/3 to 1/2 of the piston stroke and connected at one end to the crosshead centre pin by a stud and at the other end to the lever *A*. *P* is a section of a pulley, held fast to the lever *A*, with its centre at the fixed point *B*. The radius of the sectional pulley, or sector, to give a diagram of desired length can be determined as follows:

Let X equal length of lever A in inches.
Let Y equal length of engine piston stroke in inches.
Let Z equal length of desired diagram in inches.
Let R equal length of radius of sector P in inches.
Then:

$$\frac{X}{Y}(\times)\,Z = P.$$

(3)

Fig. 35, Sec. 3, shows a reducing rig as follows: Referring to the letters in the cut, B is a fixed point, from which is swung a lever A. S is a rod, which is held in a slide F, which is parallel to the engine piston H. E is a link connecting the lever A to the slide S. C is a link joining the lever A to the crosshead D. The points 1, 2, 3 must always be in the same straight line, as is shown, for the rig to give accurate results.

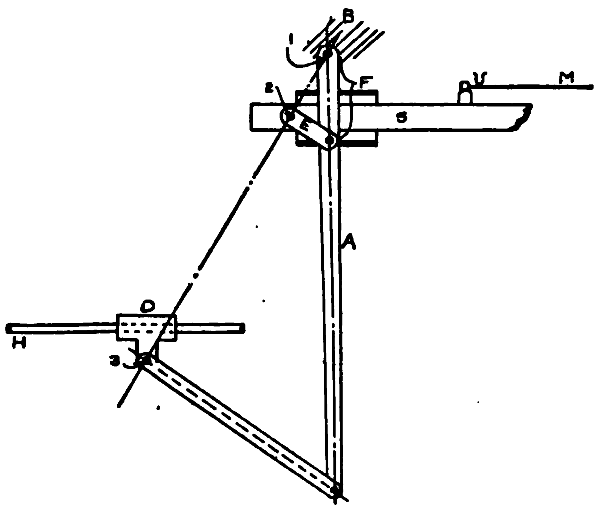


FIG. 35. SEC. 3.—Reducing rig.

If R equals the length of the link C.
If Z equals the length of the link E.
If T equals the length of the lever A.
If X equals the length of the radius V.
Then:

$$\frac{R}{Z}=\frac{T}{X}=\frac{\text{Stroke of piston.}}{\text{Length of diagram.}}$$

(4)

Reducing motion must be always adjusted so that the indicator cord will not allow the drum to strike its stop.

Reducing motions, such as the Brumbo pulley type, are not affected

by the angle at which the string is led from the guide wheel, except that it must be in the same plane vertically as the sector pulley.

Reducing motions of the pantograph type, such as shown in the preceding figure, require the indicator cord to be run in a line parallel to the motion of the piston rod.

(*g*) The method of operation for indicating an engine should be as follows:

1. Connect indicator to the cock.
2. Adjust the indicator cord as described.
3. Adjust paper on the drum of indicator.
4. Connect drum to the reducing rig by the cord.
5. Turn steam into indicator.
6. Allow indicator to warm for about a half minute.
7. Take a card, by pressing pencil mechanism against its stop.
8. Close the indicator cock and draw the atmospheric line.
9. Disconnect the indicator cord from the reducing motion. A hook and loop in the cord should be provided for this purpose.
10. The pencil lead should be kept hard and sharp.
11. For high-speed engines, make a small card and keep the drum spring tight.
12. On each card the following data should be noted. Of course, the engine constants, such as stroke, etc., remain constant, and may be taken once for the complete test:

(*a*) Time and date of test.
(*b*) Type of engine and its individual plant number, if any.
(*c*) Diameter of the cylinder.
(*d*) Diameter of the piston rod.
(*e*) Which end of cylinder card taken.
(*f*) Revolutions per minute being made by the engine.
(*g*) Length of piston stroke, inches.
(*h*) Steam gauge pressure.
(*i*) Vacuum gauge on condenser, if engine running condensing.
(*j*) Temperature of feed water.
(*k*) Scale of spring used.
(*l*) For compound engines, note the receiver pressure.
(*m*) Note the clearance volume in per cent. of piston displacement for each end of cylinder.

METHOD OF OBTAINING THE INDICATED HORSE-POWER.—To obtain the indicated horse-power of an engine from the indicator cards proceed as follows: (*a*) Determine the "effective area" of the piston thus:

1. For head end, this is the diameter of the piston in inches, squared and multiplied by 0.7854. Call this area P_h.

2. For the crank end of the cylinder, this is the area of the head end less the cross-sectional area of the piston rod. Call this area P_c.

(*b*) Determine the "piston travel" by multiplying the length of the stroke in feet by two (2), and the result by the revolutions per minute of the crankshaft. This is expressed in feet per minute and is called L.

(*c*) Determine the "mean effective pressure" for each card as follows:

1. Divide the diagram into ten (10) equal parts, as is shown in Fig. 36, Sec. 3, by lines drawn vertical to the atmospheric line.

2. Divide each area between its boundary lines by a vertical line as shown by the dotted lines, which terminate at the points where they cut the diagrams. These dotted lines are the mean heights of each small area; therefore, if each line is measured in inches and hundredths of an inch for each separate card, then the total of their lengths divided by ten (10) will give the mean height of the whole diagram. This mean height multiplied by the spring scale (which is the pressure in pounds per square inch that is required to compress the spring one inch) will give the

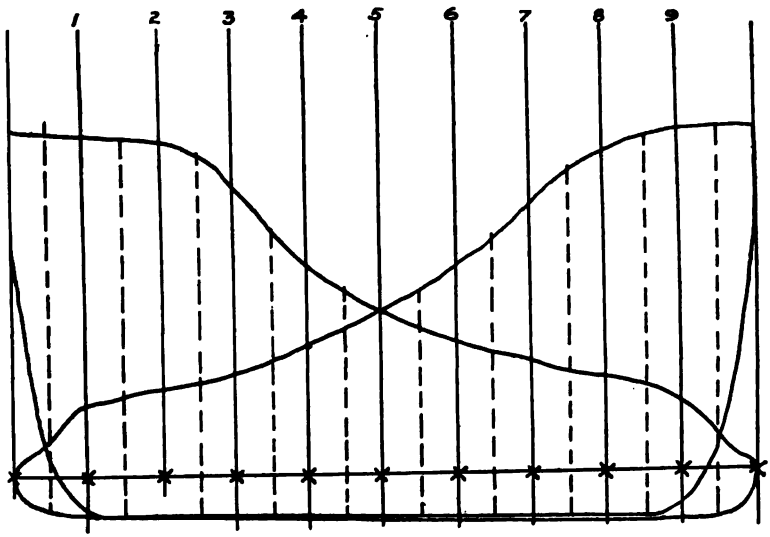


FIG. 36. SEC. 3.—Method of obtaining M. E. P.

mean effective pressure in pounds per square inch for that card. Call this the *M. E. P.*$_{c}$ or *M. E. P.*$_{h}$, depending upon which end the card was taken on.

Another good method for obtaining the mean height of the diagram is to use a strip of paper, and by sliding it along the total length is directly obtained. The M. E. P. may be then obtained by measuring this total and dividing by ten.

The M.E.P. may also be obtained by measuring the area of the card with a planimeter and dividing this area in square inches by the length of the card in inches, which will give the average height, and then multiply this result by the spring scale.

(*d*) Next, to calculate the I. H. P. (indicated horse-power) of the engine, proceed as follows:

Let P_c equal the effective area piston. (Crank end.)
Let P_h equal the effective area piston. (Head end.)
Let L equal the length of the piston stroke in feet.
Let R equal revolutions per minute.
Let I. H. P. equal indicated horse-power of engine total.

$$\text{I. H. P. (crank end)} = \frac{P_c \times M.E.P._c \times L \times R}{33000}$$

$$\text{I. H. P. (head end)} = \frac{P_h \times M.E.P._h \times L \times R}{33000}$$

$$\text{I. H. P. (total)} = \text{I. H. P. (crank end)} + \text{I. H. P. (head end)}$$

OILING THE INDICATOR.—The moving parts should be oiled with a light neutral oil of about 125 to 150 Vis. Say. at 100° F. The cylinder should be given a drop or two of a light-bodied filtered cylinder oil.

VALUE OF THE INDICATOR TO THE LUBRICATING ENGINEER.—The indicator is a valuable ally to the lubricating engineer in demonstrating the effect of various lubricants in reducing the friction load on the engine and in showing up the friction loss of transmission equipment and machinery. This is described in another section.

There is also another use for the indicator in the hands of the lubricating engineer. In his visits to the various plants coming under his attention, he should diplomatically make any suggestions to the plant engineer or superintendent which will aid them in improving the operating efficiency of their plant. There is no better opportunity offered for this than is available to those having a complete knowledge of the story told by the indicator.

Very often suggestions can be made that will gain the confidence and friendship of the plant engineer.

SOME TYPICAL ENGINE DEFECTS SHOWN BY THE INDICATOR.—As a means of recognizing some of the principal engine defects shown up by the indicator card, the following typical steam engine diagrams are given, together with the causes and remedies for each condition:

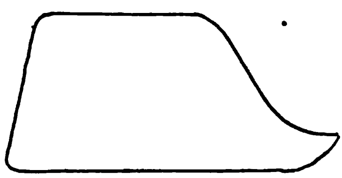


Fig. 37. Sec. 3.—Typical faulty diagram.

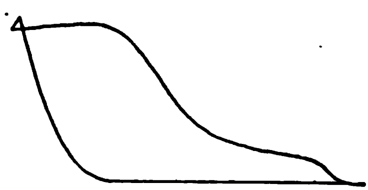


Fig. 38. Sec. 3.—Typical faulty diagram.

This card, Fig. 37, Sec. 3, shows that the eccentric has too little angular advance. Move eccentric head slightly—about 5 to 10 degrees.

Eccentric, Fig. 38, Sec. 3, has too much angular advance. Turn it back a little.

Eccentric, Fig. 39, Sec. 3, has considerably too little advance. Turn it ahead about 25 degrees.

Eccentric, Fig. 40, Sec. 3, has too much advance. Turn it back considerably. The cut-off is early, particularly if card is from a high-speed fly-wheel governor or single engine.

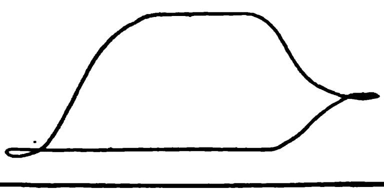


FIG. 39. SEC. 3.—Typical faulty diagram.

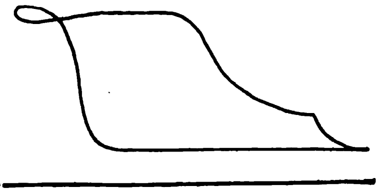
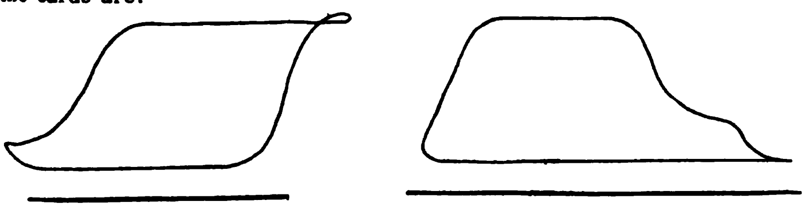


FIG. 40. SEC. 3.—Typical faulty diagram.

These cards, Fig. 41 and Fig. 42, Sec. 3, are from a plain slide-valve engine, apply equally well to an engine having a piston valve with outside steam admission.

The valve spindle is too long, and the eccentric should be set right.

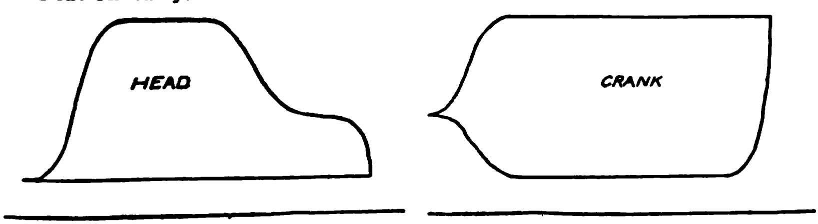
The valve spindle should be lengthened. The conditions shown by the cards are:



FIGS. 41–42. SEC. 3.—Typical faulty diagrams.

1. The steam lap on the head end is not large enough; therefore, admission is too early and cut off too late.

2. The steam lap on the crank end is too big and the admission is late and cut-off early.



FIGS. 43–44. SEC. 3.—Typical faulty diagrams.

3. The exhaust lap on the head end is too big, release too late and there is no compression.

4. The exhaust lap on the crank end is too small, release is too early and compression too late.

These cards, Fig. 43 and Fig. 44, Sec. 3, are from an engine having a plain slide valve or an outside admission piston valve. The engine is running with a valve spindle that is too long, while the eccentric has not enough angular advance. The opposite conditions of a spindle too long

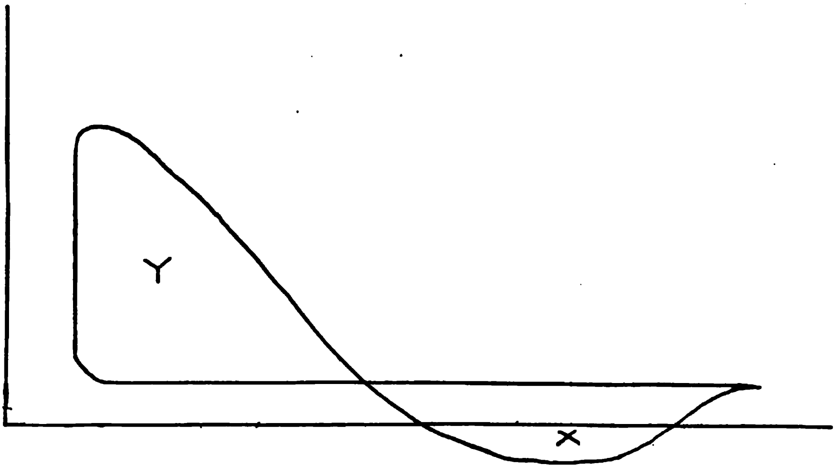


FIG. 45. SEC. 3.—Illustrates minus loop.

and the eccentric set too far ahead may be detected by comparing the four cards as shown.

There are some special points to be noted when obtaining the M. E. P. For instance, if the diagram has a loop in it, as is shown in Fig. 45, Sec. 3, the area enclosed in loop X must be subtracted from the area of loop Y.

ELECTRICAL DATA

ELECTRICAL DATA.—There are two classes of electricity; namely, static and dynamic. Dynamic electricity serves useful purposes, such as running motors, lighting, etc., while static electricity is of little practical value.

ANALOGIES TO WATER.—There are various analogies between the flow of water and electricity, which will serve to illustrate the various electrical terms, as follows:

WATER	ELECTRICITY
"Head," difference of level, in feet. Pressure, difference in pounds per square inch.	"Difference of potential," measured in volts.
"Resistance" to flow in pipes increases with length, roughness, and decrease in cross-section. Decreases as the section area increases.	"Resistance," measured in ohms. It increases directly as the length of the conductor, and decreases as the sectional area increases.
"Rate of flow," measured in cubic feet per second or gallons per minute.	"Current," measured in ampères.
"Power" is rate of work. Rate of flow in cubic feet per second times the head in feet, times the weight of a cubic foot of water, equals the power in foot-pounds per second.	"Power," measured by the watt.

DEFINITIONS.—"Electrical resistance" is measured in "ohms." An "*ohm*" is the resistance offered by a uniform column of mercury, 106.3 centimetres in length and 14.4521 grams in mass, at the temperature of melting ice, to the passage of an electric current.

"Current" is measured in "ampères." An "*ampère*" is defined arbitrarily by the electrolytic method. For practical purposes it may be defined as the current that will flow through a resistance of one ohm under a pressure of one volt.

Difference in potential is measured by the "volt." One volt is equal to the difference of potential, which will cause a current of one ampère to flow through a resistance of one ohm.

OHM'S LAW.—One of the most important electrical laws is Ohm's Law. Briefly it may be stated as follows: Current is directly proportional to the voltage and inversely proportional to the resistance.

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} \text{ (or) Voltage} = \text{Resistance} \times \text{Current}$$

Therefore, knowing two of the above values, the third can be easily determined.

THE SIMPLE DYNAMO.—An electrical dynamo is a machine to convert mechanical power into electrical energy.

A dynamo consists of two principal parts; namely, the field magnets and the armature.

If a coil of wire is rotated in a magnetic field, a current will be produced in the coil of wire. This current will flow in one direction for half a revolution, and in the opposite direction for the other half of the revolution. This pulsating current is called "alternating current."

The magnetic field may be produced by permanent magnets or by electro-magnets. A dynamo may have a number of magnets arranged around a circumference, within which a number of coils of wire, suitably joined together and called the armature, rotate. The current collected in the different coils is collected and brought out to the collecting rings.

If "direct current" is desired, the ends of the different coils are brought out to a segmented ring, called the "commutator." A direct current does not pulsate, but flows in one direction. The ends of each coil have their own segments, which are insulated from the segments of the other coils. Brushes, which are in contact with the segments, only as long as the current being generated in that coil is flowing in the desired direction, collect the current from the commutator.

The magnets are called "poles." They may be excited by a small part of the current generated by the dynamo itself, or they may be excited by a separate machine.

There are three kinds of self-excited generators, namely:

(*a*) "Shunt machines," in which only a small part of the current being generated by the dynamo passes through the field coils; that is, the field coil current is "shunted" around the main current.

(*b*) "Series machines," in which all of the current delivered by the armature is passed through the field coils; that is, the coils are in series with the armature.

(*c*) "Compound" machines, which have two coils on each pole. One coil is a series coil and the other is a shunted coil. This is the common type of generator.

ELECTRIC MOTORS.—The electric motor is the reverse of the electric generator. The current is sent through the armature, which is thus caused to revolve in the magnetic field.

COST PER HOUR OF CURRENT CONSUMED AT VARIOUS RATES PER KILOWATT HOUR

Rates per Hour in Cents

Watts Consumed	1	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10
1	.001	.0015	.002	.0025	.003	.0035	.004	.0045	.005	.006	.007	.008	.009	.01
5	.005	.0075	.01	.0125	.015	.0175	.02	.0225	.025	.03	.035	.04	.045	.05
10	.01	.015	.02	.025	.03	.035	.04	.045	.05	.06	.07	.08	.09	.10
20	.02	.03	.04	.05	.06	.07	.08	.09	.1	.012	.14	.16	.18	.2
50	.05	.075	.10	.125	.15	.175	.20	.225	.25	.30	.35	.40	.45	.5
100	.10	.15	.20	.25	.30	.35	.40	.45	.50	.60	.70	.80	.90	1.0
200	.20	.30	.40	.5	.6	.7	.8	.9	1.0	1.2	1.4	1.6	1.8	2.0
300	.30	.45	.60	.75	.9	1.05	1.2	1.35	1.5	1.8	2.1	2.4	2.7	3.0
400	.40	.60	.80	1.0	1.2	1.4	1.6	1.8	2.0	2.4	2.8	3.2	3.6	4.0
500	.50	.75	1.00	1.25	1.5	1.75	2.0	2.25	2.5	3.0	3.5	4.0	4.5	5.0
600	.60	.90	1.20	1.5	1.8	2.1	2.8	2.7	3.0	3.6	4.2	4.8	5.4	6.0
1000	1.00	1.5	1.	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0

COST OF ELECTRICAL POWER.—The table on page 129 shows the cost per hour of electric power consumed by an electrical machine when the power cost various rates.

To use the table:

1. Determine the watts consumed by the machine.
2. Find this number of watts in the "Watts Consumed" column.
3. Select the proper rate column, according to what your power costs.
4. The number of cents in this column on the same line as the number of watts consumed, as above indicated, gives the cost per hour for electrical energy to drive the machine.

Example: If the machine consumes 400 watts and the power costs five (5) cents per kilowatt hour, then from the table the cost per hour of operating the machine is two (2) cents.

CONVERSION FACTORS:

$$\text{Horsepower} = \frac{\text{Watts}}{746}$$

$$\text{Kilowatts} \times 1.34 = \text{horsepower}$$

ELECTRICAL MEASUREMENTS.—"Voltage" is measured by the "voltmeter." Current is measured by the "ammeter." These instruments are really small motors that are not allowed to rotate, but turn against the action of a spring, carrying a pointer over a calibrated scale.

TRANSFORMERS.—The office of a transformer is to change the voltage of an alternating circuit from one value to another, or to change the system from one phase to another.

The transformer consists of two separate coils of wire, insulated from each other and wound upon the same iron core. One of the coils receives alternating current at a high or low voltage, and the other coil supplies current at a low or high voltage, respectively. When the transformer receives current at a high voltage and delivers it at a low voltage, it is called a "step-down transformer." For the reverse conditions, the transformer is called a "step-up transformer."

The receiving coil is called the "primary coil," and the delivery coil is called the "secondary coil." There is always heat produced by the energy losses which occur in the core and the copper wiring in a transformer. It is, therefore, necessary to provide means for cooling the transformer. There are a number of methods of accomplishing this, namely:

(*a*) Self-cooling up to 15,000 volts.
(*b*) Self-cooling, oil-filled up to 80,000 volts.
(*c*) Cooled by air blast.
(*d*) Cooled by water.
(*e*) Cooled by water and oil.

Self-cooling by oil is the general method. The transformer is enclosed in a sheet-iron or steel case, which is filled with oil. The natural circulation of the oil carries the heat from the transformer proper to the casing, which is usually corrugated and from which the heat is radiated. In some cases the oil is circulated by a pump. Water is sometimes passed about the casing to cool the oil. Thin transformer cases should be avoided, since, in case of accident, they may be punctured and spring a leak, causing a loss of oil and possibly a fire.

For transformer oils and practical conditions, see index.

SECTION 4
PETROLEUM AND ITS PRODUCTS

ORIGIN

ORIGIN OF NAME.—The word Petroleum is derived from the Greek word *"Petros,"* meaning rock, and the Latin word *"Oleum,"* meaning oil, which combined mean "Rock Oil."

ORIGIN OF PETROLEUM.—There have been numerous theories advanced as to the origin of petroleum, and a general outline of several of these theories is given for the reader to base his own conclusions upon, for none of the theories are proven.

Some of the important investigators have been Redwood of England; Berthelot and Moissan in France; Mendeléeff and Markownikoff in Russia; Engler and Höfer in Germany; Peckham, Phillips, Sadtler, Warren, Storer and Day in America. The results of investigations made by these men have developed certain theories as to the origin of petroleum, which may be classified under two main divisions; namely, the "Inorganic Origin Theory" and the "Organic Origin Theory."

THE INORGANIC ORIGIN THEORY

This theory can be subdivided into two lines of investigations, which are those of Berthelot, and those of Mendeléeff and Moissan.

Berthelot's theory is based upon the assumption that "rock oils" are products resulting from the action of steam and carbon dioxide upon alkali metals, such as sodium.

Mendeléeff's and Moisson's theory embraces the so-called "carbon hypothesis," which indicates that petroleum was generated by the action of water upon certain metallic carbides, such as iron carbide, and as a result vapors of petroleum and deposits of iron ore were formed. This theory is based upon the similarity between acetylene and petroleum, acetylene being the commonly known product of the reaction of calcium carbide and water. While it is probably true that varying compositions of temperature and pressure might account for varying compositions of crude petroleum, the "Carbide Hypothesis Theory" has been criticized on the ground that if it were true, all petroleum crudes would have the same general composition, which, of course, is not the case.

THE ORGANIC ORIGIN THEORY

The organic theory has the largest following. There are several subdivisions of the organic theory; namely: 1. The theory that vegetable matter was the basic material. 2. The theory that the dry distillation of marine animals produced the petroleum deposits. 3. The theory that the distillation of bituminous coal at high temperatures, caused by volcanic heats, produced petroleum vapors, and that these vapors were condensed

some distance from the distillation point, leaving anthracite coal as a residue. This theory develops the question whether petroleum deposits are found at their place of origin, or whether they have moved to their present location. 4. The general opinion in America seems to favor the theory that petroleum was formed by the decomposition of organic matter, which, in some places, may have been vegetable matter and in other animal, under high pressures and comparatively low temperatures.

The Engler-Höfer theory has many followers. Höfer concludes that petroleum was formed from marine deposits. Engler carried out some experiments with the fats of marine animals, and came to the conclusion that petroleum was formed from the fatty remains of all kinds of life, which were decomposed under pressure, after the proteids had been changed by putrefaction into water, soluble nitrogen and sulphur denatures. In the course of his experiments he produced an artificial kerosene by the distillation of menhaden fish oil, which was very similar to the kerosene of commerce.

It is interesting to note that the knowledge that salt and brine are associated with petroleum deposits has been regarded as of little importance by investigating scientists in their study of the formation of petroleum. This may be an indication of the real source of petroleum.

There is another interesting point, in that, if the carbide theory is true, deposits of petroleum are probably still being formed, while if the organic, marine animal theory is the right one, the present supply of petroleum is limited.

The accumulation of Petroleum deposits depends upon the presence of a coarse-grained, porous rock to act as a reservoir. The usual "reservoir rocks" are of a sandstone nature, whence comes the well-known name of "oil sands."

RESTORATION OF OILS.—(Oildom, Oct., 1916): According to scientists, it is possible that hydrocarbons, of which petroleum is composed, may be restored by the processes of nature every 26,000 years. During which time, we are told, the position of the earth in relation to the North and South Poles, may be reversed and oil again be created in the land portion of the earth's surface.

HISTORICAL

The Egyptians made use of Bitumen in the embalming of mummies. Bitumen is of an asphalt nature. The Greeks and the Romans knew of natural earth oil long before the birth of Christ, while in other European countries there are records of Petroleum being known and used for the past three or four centuries.

In the ancient world, Petroleum was also used for building and burning, as well as for embalming. It has been mentioned in narratives of Babylon and in the Life of Alexander the Great.

In the Scriptures there are many references that can be taken to refer to petroleum. In Genesis there is a description of the building of the Tower of Babel, which relates how they used a "slime for mortar," and in Job there is a statement that "the rock poured me out rivers of oil," while in Deuteronomy is the description of "oil from out the flinty rock." The "fire worshippers," as early as 600 B. C., probably used petroleum in their practice, as we learn that followers of Zoroaster made trips to the Eternal Fires of Surakhani, on the Apaheron Peninsula (which is in the Baku district, on the Caspian Sea). These fires were probably fed by crude-oil seepages.

Pliny writes of "Sicilian oil." Marco Polo told about a fountain, toward the Georgine, a fountain that gives out oil in abundance, inasmuch as many shiploads can be taken at one time. He said: "This oil is not good to eat, but it is good to burn, and also to anoint camels that suffer from the mange."

The explorers who came to New York about 1630 found the Indians using a remedy that appears to have been petroleum oil. The Indians collected oil by placing blankets upon the surfaces of certain ponds until the blankets were saturated with the oil on the surface, when the blankets were removed and wrung out.

It seems strange that for centuries we have walked and traveled over the hidden treasures which the ill-smelling liquid, known as petroleum, has produced. In a comparatively short time, when compared to the length of time that petroleum has been observed and records made of it, one of the greatest industries in the world has been constructed, involving the production, refining, and marketing of petroleum and its products.

THE AMERICAN INDUSTRY.—The first real step in the history of petroleum in this country was made by the operations of the salt diggers. The difficulties of bringing salt from the natural sources over the Allegheny Mountains in the early days caused the salt men to investigate certain salt springs in their localities, which had been discovered by the wild animals of the region.

The salt men dug wells to secure more brine when the springs did not yield enough, and they were frequently troubled by a black, oily liquid, with a disagreeable odor. For years this oil was treated with indifference and used only for medicinal purposes.

In 1832 plants were built to distill "coal oil" from coal, to be used for illuminating purposes. The first name of this "coal oil" was kerosene. The demand for coal oil induced Kier, in 1852, to distill burning oils from petroleum instead of coal. This oil was sold in New York for as high as $2 a gallon. The first sales of the distillates were for burning

purposes, and also for scouring wool. Shipments were only in five- and ten-gallon lots. Stout & Hand, of Brooklyn, received what appears to be the first barrel of refined oil in December, 1857, and the price was 70 cents per gallon. These prices stimulated the search for petroleum, and in 1859, Drake and his stillman, "Uncle Billy" Smith, brought in the first well ever drilled for oil in the United States, on the banks of Oil Creek, in the State of Pennsylvania.

As early as 1856 petroleum from several seepages was collected and refined in a crude way. In 1892, E. S. Doheny drilled by hand a shallow well near some asphaltum deposits in the City of Los Angeles and brought in a small but steady flowing well of heavy black oil. In 1895, near the little village of Coalinga, in Fresno County, a small well was brought in, which produced the lightest oil found in the State up to that time. Soon after oil was discovered near Bakersfield and a tremendous boom started. Within three years, according to the records, some two thousand four hundred oil companies filed incorporation papers. Many of these companies failed, but the operators in Coalinga, Kern River, Midway, McKittrick, Sunset, Whittier and Fullerton were fortunate. The production in Kern River field for the first year was several times the production of the State for any year previous and the price of oil fell from $1 and $1.50 to eight or ten cents.

HISTORICAL NOTES.—Adolph Schreiner, of Austria, made the first petroleum lamp in 1850. The first lamp to have a glass chimney was devised by an unknown Englishman and was known as the Liverpool lamp.

The first oil speculators were Bosworth, Wells & Co., who bought crude oil in Virginia in 1843. This oil was sold for medicinal purposes in Philadelphia.

"Uncle Billy" Smith, who drilled the Drake well, was also responsible for setting fire to the first tank of oil.

In 1859, which year was responsible for the first commercial production of American petroleum, 1873 barrels were produced and sold. They brought an average price of $20 per barrel.

In 1797 the first oil skimmed from Oil Creek to be marketed was sold at Pittsburgh, then a collection of log cabins, for $16 per gallon.

AMERICAN PETROLEUMS

The chief fields for the production of crude petroleum in America are the Appalachian, Lima-Indiana, Illinois, Mid-Continent, Gulf, Colorado, California, etc. (See Fig. 1, Sec. 4.)

PENNSYLVANIA, OR APPALACHIAN CRUDE.—Appalachian Crude is produced along the Appalachian Mountain Range, from Wellsville, New York, through western Pennsylvania, western West Virginia, and parts of Kentucky, Tennessee and southeastern Ohio. The gravities of this crude range quite high, being from 40° to 48° Baumé (0.825 to 0.788 specific gravity). The freedom of Appalachian Crude from sulphur and other impurities makes the process of refining it simpler than for those crudes containing these impurities. Lubricating oils manufactured from this crude bring a higher price because of their excellent lubricating qualities. The cost of Appalachian crude at the wells is always higher than the prevailing prices for other crudes. Practically all cylinder stocks are manufactured from this crude.

Some of the main districts in the Pennsylvania Appalachian Field, taking them in their order going southwest, are: Allegheny, Bradford, Warren, Venango, Butler and Beaver districts.

GULF CRUDES.—These crudes are produced in the States of Texas and Louisiana.

Their gravities run from 14° Baumé to 25° Baumé. The base of Gulf Crudes is asphalt, and the finished oils made from it are generally referred to as Asphalt Base Oils.

During the refining process, the asphalt must be removed before arriving at the finished oils. Usually these oils are treated with sulphuric acid to remove the asphalt, and the acid is then neutralized. Lubricating oils that have been acid treated will not resist emulsification in the presence of moisture, and for those oils that are intended for turbine oils, forced-feed lubricating oils, etc., the asphalt must be removed by special methods, which may include filtration. Asphalt base oils, which have been carefully made as described, may give good results for turbine oils and for oils for circulating systems, so far as their non-emulsifying qualities are concerned.

Asphalt base lubricating oils are lower in flash-point, cold test and gravity than are the corresponding oils made from Northern Crudes.

The viscosities of asphalt base engine oils can be made very high without blending, but are subject to a high rate of decrease as the temperature of the oil is increased. An asphalt base engine oil may have a viscosity twice as high as a paraffine base oil at 100° F., but when the viscosities of the two oils are compared at a temperature of 150° their viscosities will have approached the same approximate value. This fact makes it necessary to select an asphalt base lubricating oil from its viscosity tests at the desired working temperature of the bearing, as no dependence can be placed on the extremely high viscosities at the standard testing temperature for engine oils, which is 100° F. The curves shown in Fig. 2, Sec. 4, are typical viscosity-temperature curves for lubricating oils made from Gulf, Mid-Continent, and Pennsylvania crudes. They illustrate the relative falling off of the viscosities of the oils made from the different crudes. It can be observed that at a temperature of 300° F. the viscosities of all the oils are approximately the same, and this is true for practically all petroleum engine oils. No cylinder oils are made from Gulf crudes.

MID-CONTINENT CRUDES.—The crude produced in the fields of Kansas, Indian Territory, and Illinois is called Mid-Continent Crude. The oil occurs chiefly in pools, which vary greatly in productiveness. When first tapped the wells show a large initial production, but quickly quiet down, with a great decrease in production.

The gravities of the Mid-Continent crudes range approximately from 27° to 40° Baumé.

Cylinder oils are being made from this crude. It is claimed that they can be made with the desired viscosities, but they have a very poor flash test as compared with Pennsylvania cylinder oils. Usually cylinder oils made from Mid-Continent Crude have about 35° to 45° F. lower flash test than oils made from Pennsylvania Crude.*

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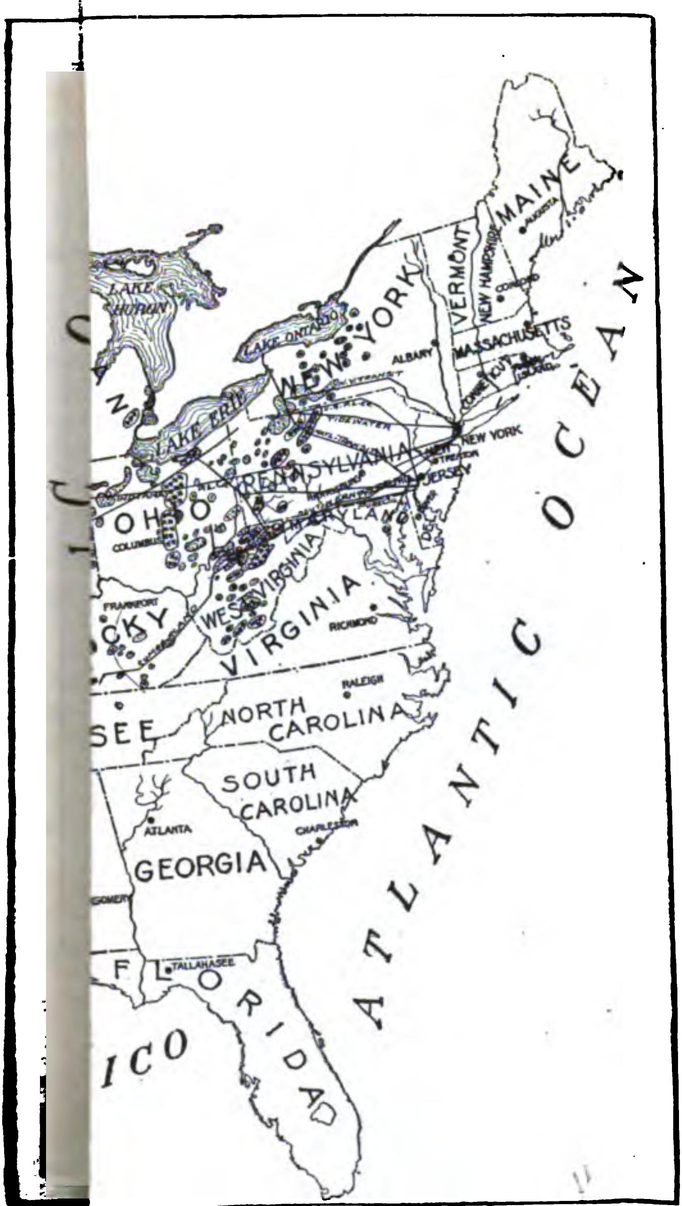
* NOTE. There are two general methods for making cylinder stocks from


LAKE HURON
LAKE ONTARIO
LAKE ERIE
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
AUGUSTA
CONCORD
MASSACHUSETTS
ALBANY
NEW YORK
PENNSYLVANIA
JERSEY
OHIO
COLUMBUS
MARYLAND
WEST VIRGINIA
VIRGINIA
RICHMOND
FRANKFORT
CKY
NORTH CAROLINA
RALEIGH
SEE
SOUTH CAROLINA
CHARLESTON
ATLANTA
GEORGIA
TALLAHASEE
FLORIDA
ICO
ATLANTIC OCEAN

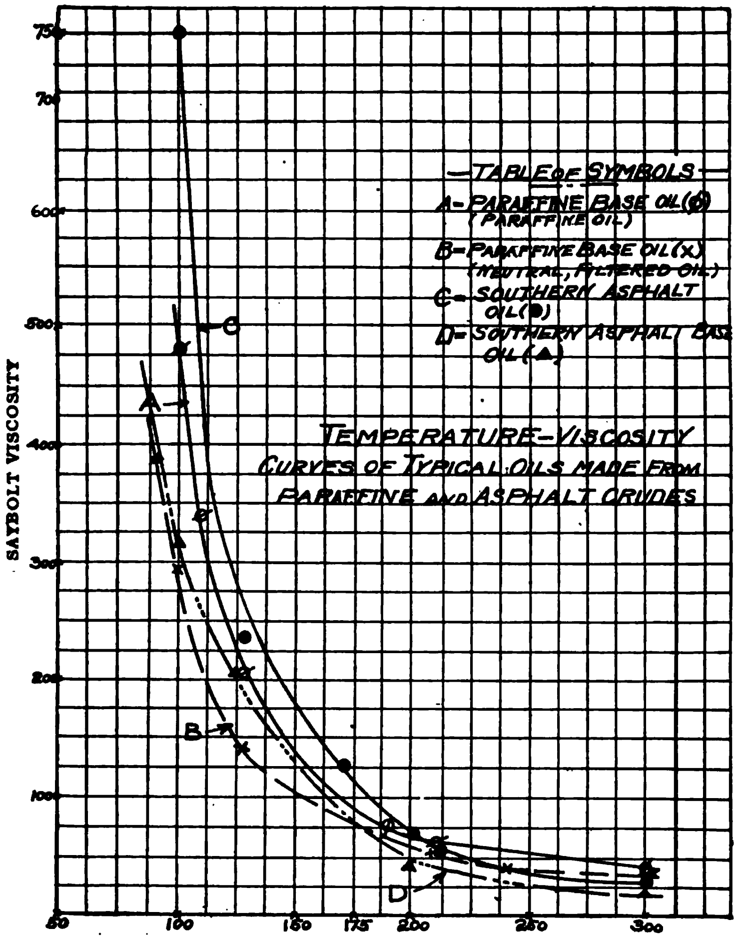


FIG. 2. SEC. 4.—Temperature-viscosity of engine oils made from paraffine and asphalt base crudes.

The chart on page 141 was prepared in the laboratories of Cosden & Company, at West Tulsa, under the direction of Dr. Charles K. Francis, chief chemist.

Mid-Continent Crude. One method is to top the crude, taking off the gasolines, and to then blow the bottoms with acid for a short time and treat. The sludge runs from about 6 per cent. to 25 per cent., depending upon the crude, and averages about 18 per cent. The treated oil is then handled as an amber crude. The other method, which is troublesome, is to reduce with steam to about 250° F., and then cut the bottoms with kerosene and treat. This may

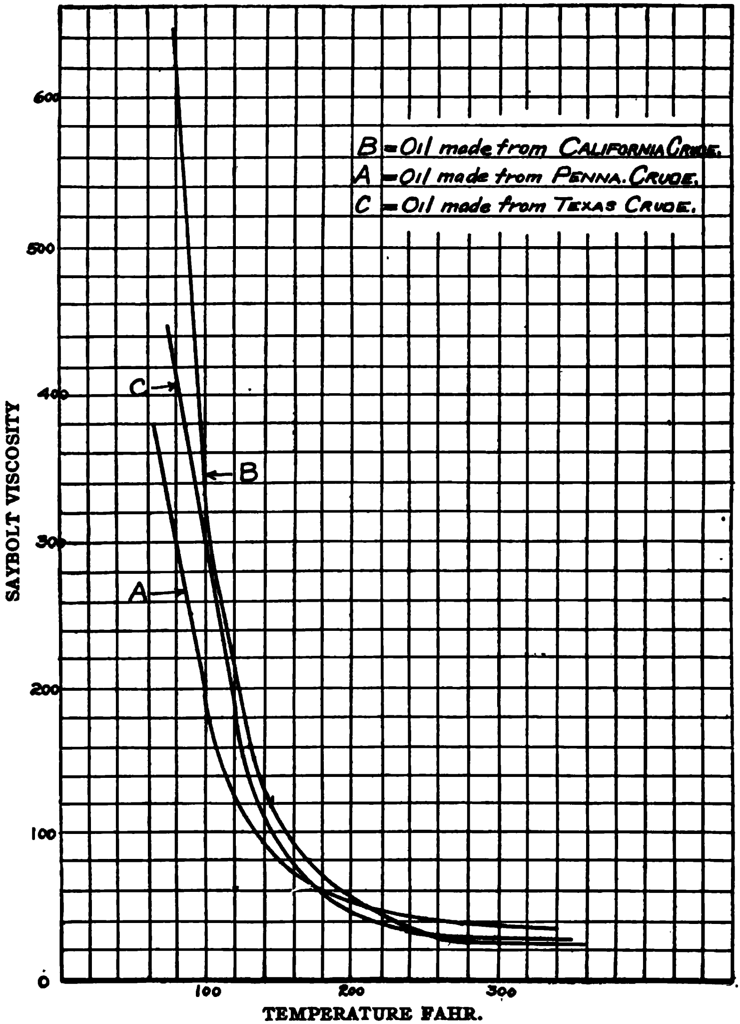


FIG. 3. SEC. 4.—Comparison of viscosities of engine oils made from California, Appalachian, and Texas crudes.

In each case the gravity, initial boiling point and b.s. content of the crude are shown, together with its content of benzine, naphtha and bottoms.

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give a difficult mixture to settle and filter, and is not so satisfactory or commercially practical as the first method described.

The extent to which the Texas crudes are available for cylinder stocks

The product designated as bottoms in the chart includes the gas oil and the product which contains the wax distillate, or lubricating stock, and which is sold as fuel oil by the skimming plant operator.

The results shown in the chart were obtained from laboratory distillation tests, made by running down 1000 cubic centimetres of each crude. No losses are shown, but the loss runs from 1.5 to 3 per cent., with the average probably slightly above 1.5.

LIMA-INDIANA CRUDE.—This crude is slightly higher in gravity than the Mid-Continent crudes, ranging in gravities from 35° to 41°

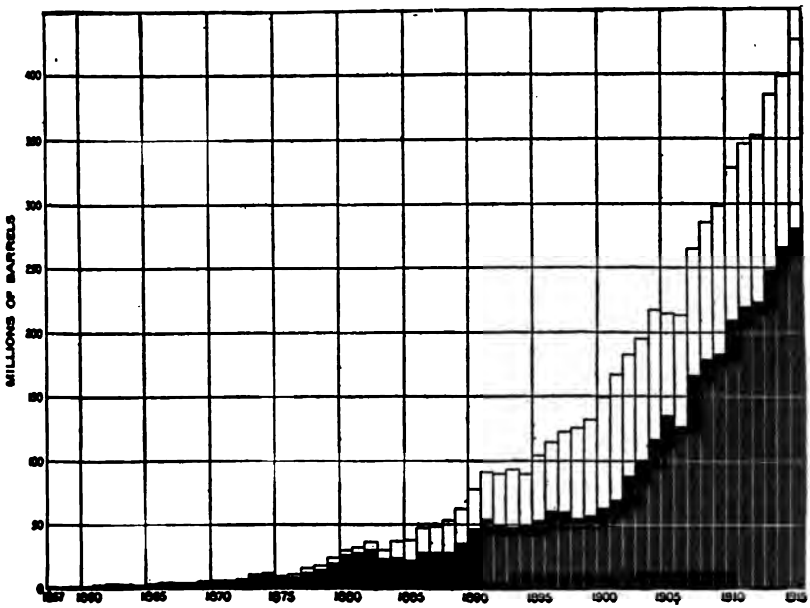

FIG. 4. SEC. 4.—Graphic chart showing world's production of crude petroleum, 1857-1915, inclusive, and the proportion contributed annually by the United States (indicated in black).—U. S. Geological Survey.

Baumé. This field is frequently referred to as the Trenton Rock Field, due to the large amount of Trenton limestone found there.

The oil appears in pools and is not widely distributed. It produces

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and bright stocks in refinery turnout is limited to the supply of Ranger crude from the general black lime producing area of North Texas, which has a paraffine base. South Texas crudes do not yield either cylinder or bright stocks, being of asphalt base. Ranger crude differs from the gasoline crude produced in the Wichita Falls "sand country" district, although the raw product from the black lime country does yield better than 20 per cent. of the lighter fractions, leaving 20 per cent. of the heavier cuts available for cylinder and bright stocks.

a large percentage of lubricating oils, but practically no cylinder stocks are made from it. There is a good deal of sulphur in the crude, and it must be carefully removed by suitable processes.

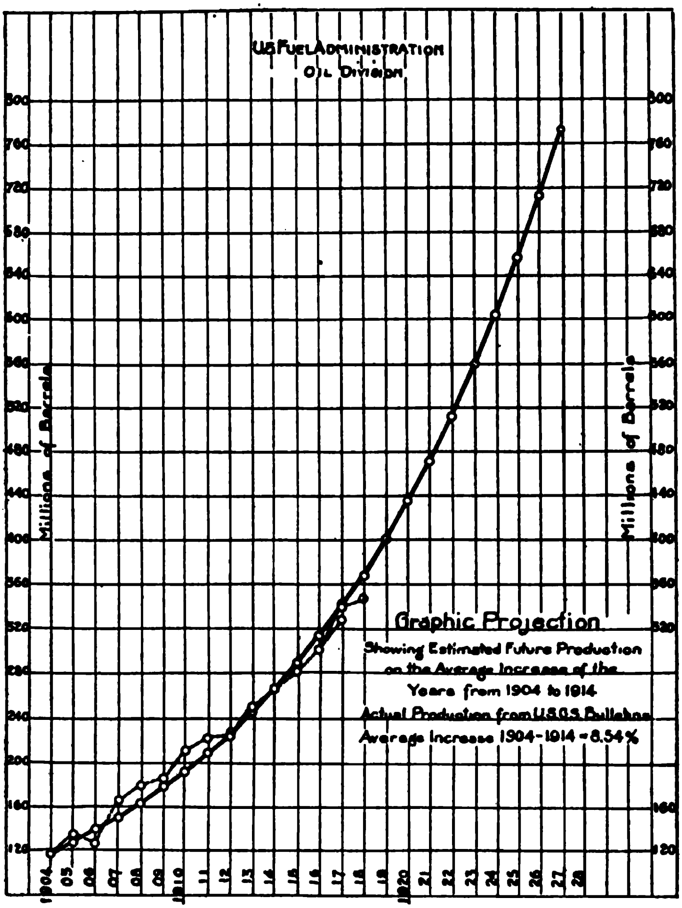


Fig. 5. Sec. 4.—The estimated future production of crude petroleum in the United States on the basis of the recent rate of increase. The growth in output indicated can scarcely be expected in view of the size of the reserve (see Fig. 6), which means that increasing imports and increasing efficiency in utilization must come into play. (Taken from U. S. Fuel Administration Bulletin.)

CALIFORNIA CRUDE.—The California oil fields exist chiefly in the southern half of the State. This crude is heavy, its gravities ranging from 3° Baumé to 35° Baumé. The production for the State averages 16.5° B.

The lubricating oils made from this crude have very similar characteristics to those made from Gulf asphalt-base crudes.

The curves shown in Fig. 3, Sec. 4, are typical temperature-viscosity curves, showing the comparison of the viscosities of a California and an Appalachian base lubricating oil.

The viscosity of California oil falls very rapidly. For instance, a

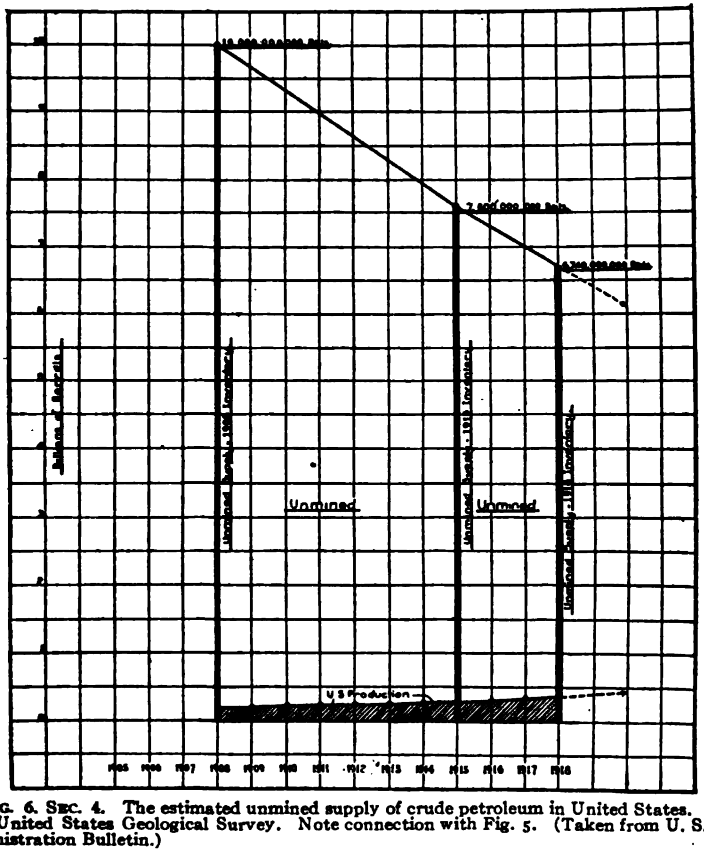


FIG. 6. SEC. 4. The estimated unmined supply of crude petroleum in United States. Data from United States Geological Survey. Note connection with Fig. 5. (Taken from U. S. Fuel Administration Bulletin.)

14° or 16° oil will have a viscosity at 110° F. of from 1/8 to 1/10 the viscosity at 60° F. Above 110° F. the decrease is much less rapid.

The flash-point of California Crude ranges from 400° F. down to 60° F. Most of the oil which is classed as fuel oil flashes above 150° F.

Oil refining in California is divided into two distinct classes, namely: The refining of light oil, for the usual products, and the refining of the heavy asphaltic oil, to produce asphalt. Some of the refined products obtained are: Gasoline, benzine, engine distillate (56° to 40° B.), kerosene

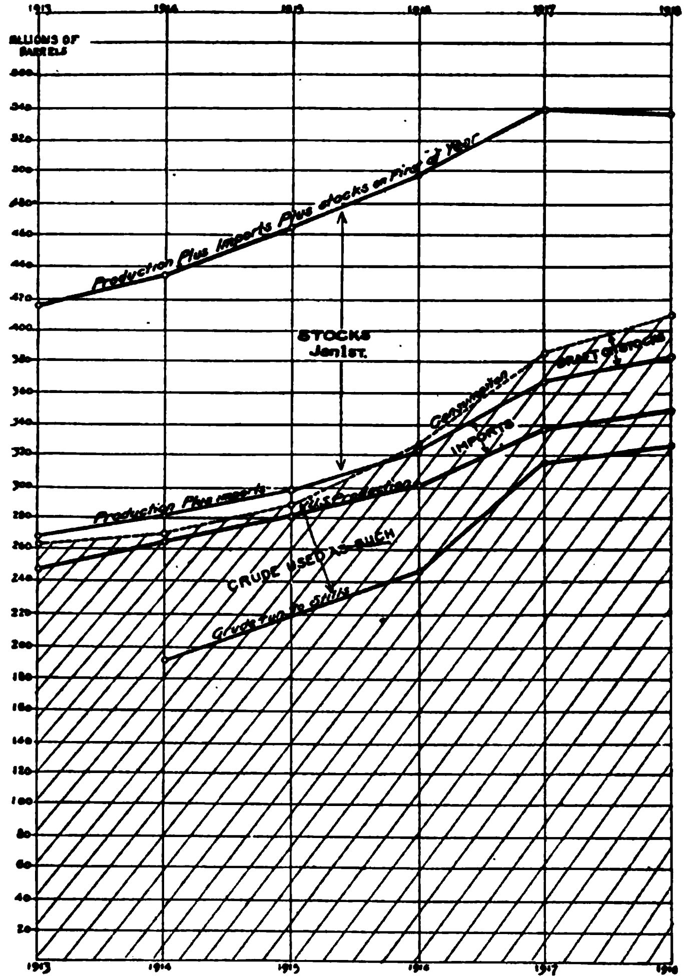


FIG. 7. SEC. 4.—The crude petroleum situation in the United States, 1913-1918, showing the relation between marketed production, imports, stocks, refinery consumption, and total consumption. Data from United States Geological Survey, United States Bureau of Mines, and United States Fuel Administration.

(44° to 42° B.), store oil (35° to 32° B.), gas oil (30° to 28° B.), fuel distillate, neutral oils, light lubricants, engine oils, car oils, etc.

The lubricating oils are fair, but the flash points are low and the viscosity rapidly decreases on heating. The cold test is very low.

COMPOSITION OF TWENTY-SEVEN MID-CONTINENT CRUDES

(Dr. C. K. Francis, in *National Petroleum News*.)

CRUDE	ANALYSIS							TESTS ON PRODUCTS											
								BENZINE			NAPHTHA			KEROSENE			BOTTOMS		
Showing State and District	Grav.	I.B.P.	% B.S.	% Benz.	% Naph.	% Kero.	% Bot's	Grav.	I.B.P.	Dry	Grav.	I.B.P.	Dry	Grav.	Flash	Fire	Grav.	Flash	Fire
	Be.	Fahr.						Be.	Fahr.	Fahr.	Be.	Fahr.	Fahr.	Be.	Fahr.	Fahr.	Be.	Fahr.	Fahr.
OKLAHOMA																			
Beggs	32.7	120	Trace	15.00	08.60	13.20	63.20	59.3	132	440	49.5	222	...	41.7	130	156	24.4	290	335
Bixby	34.5	150	0.9	20.13	...	20.35	59.62	57.3	134	448	...	...	...	42.5	128	148	26.3	250	284
Birdcreek	30.9	176	0.8	9.60	...	15.00	75.00	51.3	166	458	...	...	...	43.9	R T	R T	28.6	255	235
Cement	36.1	110	...	15.00	7.50	17.50	60.00	58.1	156	504	49.8	258	510	43.7	144	172	28.0	275	340
Cushing	39.4	138	0.6	35.00	...	15.00	50.00	58.2	132	460	...	...	...	42.2	132	166	25.7	290	330
Drumright	38.7	...	...	30.00	...	20.00	50.00	57.9	138	457	...	...	...	43.3	124	150	27.2	270	330
Duncan	33.7	150	.03	27.20	...	15.00	57.80	59.2	140	490	...	...	...	42.6	140	168	21.7	265	305
Garber	47.1	117	.80	55.00	...	20.00	25.00	60.9	127	451	...	...	...	42.8	135	164	27.7	310	370
Hominy (Osage)	37.7	140	.12	25.00	...	20.00	55.00	58.8	136	444	...	...	...	43.7	110	130	27.6	260	300
Healdton	30.4	...	.10	10.00	...	23.00	57.00	57.9	118	442	...	...	...	42.5	R T	88	...	...	...
Inola	36.2	...	2.00	27.50	...	22.50	50.00	58.8	132	450	...	...	...	42.1	128	144	...	...	...
Jenks	32.8	220	.30	15.00	...	20.00	65.00	51.1	244	512	...	...	...	44.1	115	134	26.1	260	300
Madill	46.6	...	.06	50.00	...	20.00	30.00	59.1	132	...	...	...	...	41.8	170	202	...	...	...
Mervine	40.8	116	Trace	22.50	10.00	20.00	47.50	58.3	176	454	51.6	244	490	43.4	133	155	29.9	275	330
Mounds	34.7	...	...	20.00	...	15.00	65.00	58.3	138	448	...	...	...	44.0	96	130	25.6	280	330
Quay	35.3	160	.15	27.50	...	15.00	57.50	56.5	162	490	...	...	...	44.4	122	140	29.6	386	334
Walters	29.8	...	...	25.00	...	10.00	65.00	57.0	...	...	...	...	...	42.5	...	...	...	...	...
Youngstown	42.1	...	.02	35.00	...	20.00	45.00	58.5	150	464	...	...	...	43.3	144	158	...	...	...
KANSAS																			
Augusta	41.1		.10	30.00	...	22.50	47.50	9.2	148	458	...	...	...	44.0	130	142	...	...	...
Chautauqua	35.5	136	.60	27.50	...	10.00	62.50	58.5	130	480	...	...	...	42.6	125	150	27.2	290	340
Greenwood Co.	34.5	126	.34	15.00	...	35.00	50.00	58.1	162	474	...	...	...	42.0	120	140	...	...	...
Iola	19.1	...	4.00	(Wax Dist. 50.00%—Bot's 46.50%, Loss 3.50%) (Wax Dist. Tests. Gr. 30.3; Fl. 150; Fire 230; Visc. 51)															
LOUISIANA																			
Pine Island	26.7	218	Trace (Gas Oil 10.00%; Wax Dist. 87.00% Bot's 3.00%) Gas Oil· Grav. 35.4; Flash 100; Fire 120) (Wax Dist.: Grav. 30.9; Flash 120; Fire 205; Cold 20; Vis. 42)																
TEXAS																			
Burkburnett	39.8	100	...	42.50	...	7.50	50.00	58.2	124	482	...	...	...	41.5	140	184	26.1	260	310
Moran	34.7	170	.46	10.00	11.00	17.50	61.50	58.8	150	444	50.7	220	...	42.5	120	136	28.4	255	295
Ranger	37.3	156	.70	20.60	7.72	17.84	51.90	58.5	136	342	48.8	229	440	42.8	168	190	27.7	300	350
San Antonio	32.8	170	.01	24.00	...	12.50	63.50	39.2	144	510	...	...	...	42.4	156	178	23.3	255	310

PERCENTAGES OF PRODUCTS PRODUCED FROM CRUDE OIL IN THE U. S. DURING THE FIRST SIX MONTHS OF 1917

(Figures are not absolutely correct, but substantially so.)

Source	Gasoline Per cent.	Kerosene Per cent.	Gas. and Fuel Oil Per cent.	Lubricating Per cent.	Loss Per cent.
East Coast	22	22	25	11	7
Pa., E. Ohio, W. Va., and N. Y.	24.6	21	23	23	4
W. Ohio, Ind., Ill., Ky., and Tenn.	36	14	25	9	4.8
Okla. and Kans.	27	14	48	1.5	2.8
Colo. and Wyo.	37	17	52	0.5	9
Tex. and Louisiana	12	11	45	27	2.7

Average yields for entire country first six months of 1917 are: Gasoline, 20%; Kerosene, 13%; gas and fuel oil, 44%; lubricating oil, 5.8%; loss, 3.6%.

APPROXIMATE GRAVITIES OF VARIOUS AMERICAN CRUDES

Field	Baumé gravities	Specific gravities
Appalachian (excluding Franklin)	40–48	.8235–.7865
Lima, Indiana	35–40	.8484–.8235
Illinois	28–40	.8860–.8235
Mid-Continent	28–40	.8860–.8235
Colorado (Florence)	30–32	.8750–.8641
Gulf	14–25	.9722–.9032
Corsicanna (excluding Powell)	40	.8235
California	12–30	.9859–.8750

AVAILABLE OIL REMAINING IN GROUND, AS ESTIMATED BY THE U. S. GEOGRAPHICAL SURVEY

(Barrel of 42 gallons)

Oil fields	Marketed production in 1917	Marketed production in 1918 (preliminary estimate)	Total marketed production to end of 1918	Available oil left in ground, January, 1919	Present average gasoline extraction, per cent.
Appalachian	24,932,205	25,300,000	1,221,737,000	550,000,000	28.0
Lima, Indiana	3,670,293	3,100,000	448,404,000	40,000,000	20.0
Illinois	15,776,860	13,300,000	298,159,000	175,000,000	22.0
Mid-Continent	144,043,596	139,600,000	990,573,000	1,725,000,000	24.0
North Texas	10,900,646	15,600,000	78,971,000	400,000,000	33.0
North Louisiana	8,561,963	13,000,000	90,902,000	100,000,000	28.0
Gulf	24,342,879	21,700,000	303,954,000	750,000,000	1.5
Wyoming	8,978,680	12,370,000	39,793,000	400,000,000	40–50
California	93,877,549	101,300,000	1,114,000,000	2,250,000,000	12.0
Alaska, Colorado, Michigan, Montana, etc.	230,930	230,000	10,651,000	350,000,000	....
Total	335,315,601	345,500,000	4,598,144,000	6,740,000,000	....

UNITED STATES REFINERY PRODUCTION (1918)

(Bureau of Mines)

	East coast (N. Y., Phila., and Balto.)	Pa., N. Y., (E. Ohio and W. Va.)	W. Ohio, Ind., Ill., Ky. and Tenn.	Oklahoma and Kansas	Texas and Louisiana	Colorado and Wyoming	California	Total
Crude run (bbls.)	64,119,528	18,804,510	22,184,148	60,805,183	81,733,167	11,913,125	66,454,969	326,024,630
Re-run (bbls.)	7,330,083	1,992,336	7,987,413	9,378,896	5,579,957	4,627,512	13,669,007	50,565,204
Gasoline (gals.)	718,720,111	241,639,462	460,795,843	865,799,574	636,856,670	212,108,809	434,392,494	3,570,312,963
Kerosene (gals.)	485,559,229	136,951,334	187,070,255	415,222,396	435,281,246	62,695,223	102,580,454	1,825,360,137
Fuel, gas oil (gals.)	1,118,998,731	201,775,157	344,497,236	1,344,145,229	1,934,441,119	243,755,929	2,133,784,156	7,321,397,557
Lubricants (gals.)	257,412,655	182,864,252	97,460,092	109,876,505	123,258,451	3,653,559	66,940,253	841,465,767
Wax (lbs.)	215,791,443	86,432,928	78,020,865	48,726,352	73,145,391	2,259,346	768,032	505,144,357
Coke (ton)	222,644	19,758	137,759	56,659	107,931	14,912	....	559,663
Asphalt (ton)	270,172	2,900	71,942	10,434	145,887	40	106,593	607,968
Miscellaneous (gals.)	78,617,550	36,308,371	43,476,748	68,125,328	352,028,239	136,475,995	571,678,155	1,286,710,383
Loss (bbls.)	3,631,988	1,187,926	1,890,377	2,525,447	3,019,166	732,931	1,568,790	14,556,625

FOREIGN PETROLEUMS

MEXICAN PETROLEUM PRODUCTS.—The following data were covered in an address prepared by R. De Golyer, consulting geologist of New York, and delivered before the motor fuel session of the Society of Automotive Engineers in New York, February 6, 1919, as reported by the *National Petroleum News:*

" Mexico, with its production of approximately 67,000,000 barrels in 1918, apparently achieved second place among the petroleum-producing nations of the world. The United States, with a marked production of some 345,000,000 barrels, was secure in first place, but it is certain that revolution-ridden Russia could not have produced enough of its normal 60,000,000 to 70,000,000 barrels to enable it to retain second place.

" This position, now gained by Mexico, will soon be relinquished. The potential production since 1911, the year in which Mexico became an exporter of petroleum, has been far in excess of the actual production, which in the past few years has been limited by the serious tank steamer shortage resulting from the great war. With the ending of the war, the tankers are being rapidly released and many of them are going into the Mexican trade. Petroleum for the present year is likely to be greatly in excess of that of 1918.

" There are two general regions in Mexico from which petroleum has been produced—the highly important Tampico-Tuxpam region and the less explored Tehuantepec-Tabasco region. The Tampico-Tuxpam region, which includes the section of the Gulf Coastal plain adjoining the ports of Tampico and Tuxpam, is the region from which practically the entire commercial production of Mexico comes at the present time.

" The fields of the Tampico-Tuxpam region are divided generally into two groups—those of the Panuco River valley region and those of the southern or Tuxpam region. The fields of the Panuco River valley region, including the Panuco, Ebano-Chijol, and Topila pools, produce heavy viscous petroleum of 10° to 13° Baumé gravity, which are used principally in their crude state as fuel oils. The fields of the Tuxpam zone, including Potrero del Llano, Casiano-Tepetate, Cerro Azul, Los Naranjos, Alamo, and Furbero pools, produce lighter petroleums of 19° to 22° Baumé gravity, which are the Mexican petroleums used generally for refining purposes.

" Approximately 69 per cent. of the petroleum produced in Mexico in 1917, the last year for which detailed statistics are as yet available, was of this grade, and 31 per cent. was of the heavier Panuco grade. The proportion of the lighter crude was probably even greater in the production of the past year. Of the 1917 Mexican petroleum production, some 77.6 per cent. was exported. Exports for the past year show an even greater percentage and will increase as the Mexican production increases. Of the petroleum remaining in the country during 1917, the equivalent of 5.2 per cent. of the total production represents fuel consumed by the Mexican railways and 1.5 per cent. represents petroleum consumed principally as fuel in the industry itself. The remaining 15.5 per cent. of the total production includes petroleum and products consumed in Mexico, refining losses, increase in storage, if any, etc.

"The use of crude Mexican petroleum in internal-combustion engines has not yet passed beyond the experimental stage, but more and more crude petroleum is being refined for its light oil products, and this forms an increasingly important addition to the world's supply of engine fuel. The Mexican Eagle Oil Company, Ltd., has refineries at Minatitlan and Tampico, and a topping plant at Tuxpam. The Waters-Pierce Oil Company has refineries at Vera Cruz and Tampico. The Standard Oil Company of New Jersey has a refinery at Tampico. The Texas Oil Company has topping plants at Port Lobos and Tampico. The Doheny interests have a topping plant at Tampico and an asphalt plant at Ebano. The Atlantic Refining Company has a topping plant at Port Lobos.

"Only the 19° to 20° Baumé petroleums of the Tuxpam region are refined in quantity in Mexico. All of the refineries and topping plants run it except the Tampico plant of the Texas Company, which tops some Panuco crude, the Ebano asphalt plant, which runs Ebano crude, and the Tampico refinery of the Waters-Pierce Oil Company, which runs a very small amount of Topila crude besides much greater amounts of Tepetate-Casiano, Naranjos and Potrero crudes.

"Panuco crude is used mostly for fuel purposes. It is so viscous that after the very small light oil fraction has been removed, the residue can be handled only with the greatest difficulty and by specially designed equipment. Panuco crude is imported to the United States and, after being mixed with Gulf Coast crudes, is successfully refined. One American refinery is reported to crack Panuco crude, thus securing 12 to 16 per cent. of gasoline or engine fuel.

"The greatest possibilities for future extended uses of Mexican petroleum seem to lie either in the future perfection and more widespread development of internal-combustion engines using very heavy oils as fuel, or in an improvement of refining methods by which heavy oils can be more easily converted into lighter oil. It is likely that both methods will be utilized. In the past several years the continued development and widespread use of internal-combustion engines have created such a demand for fuel that it has been supplied only by great efforts on the part of the producer and refiner of petroleum. Fortunately for the petroleum industry, this demand has set the mark, and the internal-combustion engine has not waited to be assured of a source of supply for a fixed number of years in advance.

"Statistics covering the production of petroleum by years since the beginning of the industry have recently been made public by the Petroleum Commission of the Mexican Government. They show the past history of Mexican petroleum and indicate prospects for future increases in production better than can be done in any other manner.

"Lubricating oils are also being made from certain kinds of Mexican crudes. Some of the crudes have been found to yield a commercial amount of wax."

RUSSIAN OIL.—In 1915, according to reports, the wells in the Baku region produced 80 per cent. of the output, and Grosny, on the Caspian, 15 per cent. Other Russian producing regions are Maikop, on the Black Sea; Emba (field), in the Ural Mountains.

Year	Bbl.	Metric tons.	Year.	Bbl.	Metric tons.
1901	10,345	1,544	1911	12,552,798	1,873,552
1902	40,200	6,000	1912	16,558,215	2,471,375
1903	75,375	11,250	1913	25,696,291	3,835,267
1904	125,625	18,750	1914	26,235,403	3,915,732
1905	251,250	37,500	1915	32,910,508	4,912,016
1906	502,500	75,000	1916	40,545,712	6,059,589
1907	1,005,000	150,000	1917	55,292,770	8,264,266
1908	3,932,900	587,000	1918 (estimated	57,000,000	10,000,000
1909	2,713,500	405,000			
1910	3,634,080	542,400			
			Total ...	289,082,472	43,166,241

Baku oils are asphaltic and most of the output is marketed as kerosene and fuel oils.

Grosny oils are said to be of higher grade and yield some gasoline.

This crude has been one of the largest competitors of American crude in production until the Mexican fields came in. The chief oils made from it and on the American market are those oils known as "Russian White Oils," which are largely used for medicinal purposes and for adulteration of vegetable oils. They are free from any cast or bloom which would detect their presence when used as an adulterant.

ARGENTINE OIL.—The increase in oil production in Argentina is interesting. In 1911 only 1920 tons were the output and in 1918 the yield was 200,000 tons. There has been a new field developed on the southern branch of the Great Southern Railway, and the oil is said to be of better quality than that from the Commodore Rivadavia district. The Mendoza and Neuquen sections close to the oil fields are being explored (1919). Oil as far south as Argentina will be a valuable source of supply to oil stations on the Falkland Islands to supply fuel to ships that go around the Horn.

OTHER CRUDES.—The other countries producing petroleum are: Roumania, Japan, Austria-Hungary, Dutch East Indies, British India, and, in a small way, Canada and Germany.

PETROLEUM PRODUCTION

DRILLING OPERATIONS.—A general description of the drilling operations may be of interest to the industrial oil engineer who desires a complete general knowledge of the petroleum industry.

While there are many special and individual methods of oil-well drilling, we may state that in general in those sections where the formation is hard and firm, such as in the Eastern and Northern States and in Oklahoma, the cable tool drilling apparatus is employed.

In Texas, Louisiana and the Gulf States the usual method used is the rotary system.

In California the system used is a combination of the above-named two.

"Cable drilling" requires a derrick, which is about eighty feet high and is equipped with a "walking beam," through which power is imparted by means of manila or wire roping to a "string of tools," which is carried at the end of the cable. The "string of tools" usually consists of the

following: A rod socket, a long stem, called a sinker, which is about 40 feet in length and about 5 inches in diameter. Then comes a set of "jars," which provide a whipping movement, and at the bottom is a large "bit." For a deep well, the hole is started with a diameter of about 18 to 20 inches, and this diameter is gradually reduced as the well gets deeper, so that at the production formation the diameter of the bore is about 5 or 6 inches. (See Fig. 8, Sec. 4.)

The hole is drilled down until due to water and caving of the sides progress is stopped, when it is then cased with pipe, when drilling again is resumed and a slightly smaller bit used.

The so-called oil formation is a porous sand and rock formation, which is saturated with oil, and the productivity of the well is dependent upon the thickness and extent of this formation. Often when the bore has reached this formation, the pressure present is sufficient to cause the oil to start to flow up the casing and out at the top with great violence. Usually, however, it is necessary to continue the bore through the producing sand and to then set off a charge of nitroglycerine in order to start the well flowing.

ROTARY DRILLING.—With this system a long tube is suspended from the top of the derrick, and at the end of this tube is a bit with a hard cutting edge. By means of a friction drive, the tube and cutting tool are made to turn. In order to remove the waste material from the bore, water is pumped down through the tube and out at the bottom, so that as it washes up through the casing and out at the top of the well it carries with it the borings.

After the well has stopped flowing, it is fitted with a string of two-inch pipe, which is put down through the outer casing, and a small pump that is driven usually by a long rod is attached at the bottom. A "pump jack" gives this rod an up and down motion. The pump jack is driven from a central power house and often 15 or 20 wells are pumped from the same station.

PIPE LINES.—After the oil has come from the well, either by pumping or by natural flow, it is passed to the "flow tank," where it is settled, and then is passed to a larger tank. When the large tank is filled, a representative of the pipe line company gauges it, and the oil is then run into the pipe line connection which is tapped into it.

A "run ticket" which is a form of receipt, is given to the well owner by the pipe line representative. The oil is now the property of the pipe line company, and settlement is made on the basis of the run ticket. Of course, as soon as the oil has passed into the pipe line, it loses its identity and becomes mixed with the other oil coming from that field.

The original owner of the oil or the well operator can sell the oil called for on his receipt on the basis of the prevailing market price on the day it was run. In some cases the holder of the receipt can let the oil stand in the pipes to his credit, and any time within 60 days dispose of it, or, in other cases, he can store the oil with the pipe line company in their tanks at a special storage charge, so that he can wait for a market rise if he believes one is due.

The main lines, or trunks, are built of steel or wrought-iron pipe and run at about 6 or 8 inches in diameter. In order to prevent the flow of

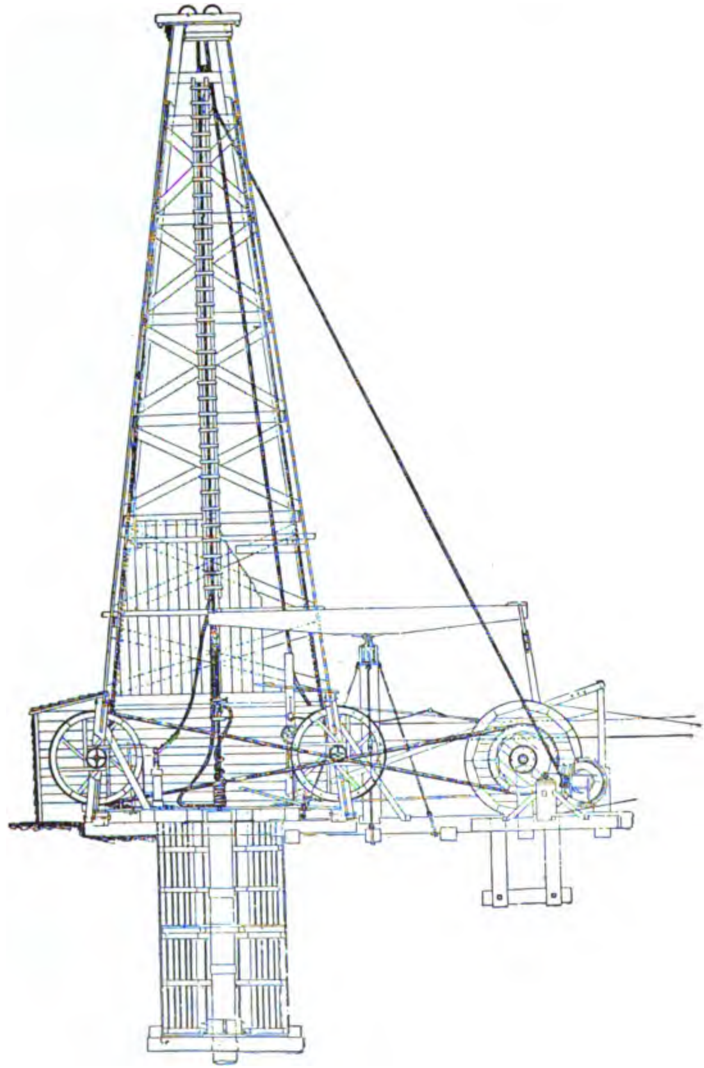


FIG. 8. SEC. 4.—Rig for cable-tool drilling.

the oil from being hindered, due to sluggishness produced by low temperature, the pipe lines are laid below the frost line.

OIL PIPE LINES. ESTIMATED COST OF TRANSPORTING OIL.—(S. A. Sulentic. Paper presented December, 1919, A.S.M.E.) Mr. Sulentic states: " * * * A very crude estimate of the cost of trans-

porting oil by pipe line when using equipment of the highest economy can be estimated by assuming a single line operating under the following conditions, at a load factor of 80 per cent., for 300 days per year:

Size of line	8 inches.
Length of line	33 miles.
Pressure in line	700 pounds per sq. in.
Rate of discharge	900 barrels per hour.

"At this rate the discharge would be 21,600 barrels per day, or 6,480,000 barrels per year of 300 working days. Assuming 6.5 barrels per ton, the yearly discharge would be approximate 1,000,000 tons. The work equivalent of this discharge would be 33,000,000 ton-miles, calling for a continuous expenditure of 257 horse-power. Assuming a mechanical efficiency of the engine of 75 per cent., the actual horse-power necessary to install would be 342.

"The assumed costs would be as follows:

Line: 33 miles at $1.65 per foot	$287,500	Tanks—Two 55,000-barrel at $18,500 each	$37,000
Right of way at $0.25 per rod	2,640	Two 500-barrel at $500 each	1,000
Freight: 79 cars at $250	19,750	Telegraph line: 33 miles at $550	18,150
Haulage: 900 tons at $14.50	13,050	Superintendence	2,500
Laying pipe at $0.075 per foot	13,060	Incidentals	6,000
Burying pipe at $0.20 per foot	34,850		
Engines, pumps, installed accessories	68,500		
Pump stations, buildings and foundations	30,000	Total	$534,000

"The operating expense, including fixed charges based on the total assumed costs, would be as follows:

Interest at 6 per cent.	$32,040	Repairs to equipment, lines, etc.	$4,000
Depreciation at 5 per cent.	26,700	Fuel for pumping, 3000 barrels at $2.65	7,950
Administration	10,000		
Attendance at pump stations and lines	11,500		
		Total	$92,190

"The cost of operation under the assumed conditions per ton-mile would, therefore, be:

$$\frac{92,190}{33,000,000} = \$0.0028$$

"* * * It should be noted * * * that almost all pipe-line costs are fixed and are mainly independent of the amount of oil pumped. As a result, the cost of transportation per ton-mile will vary almost inversely with the load factor of the line. * * *"

"In illustration of the foregoing, the following data in regard to the 36-mile, 8-in. Alton pipe line, operating between Carlton and Wood River, Mo., will prove of interest. This line, constructed in 1913, has four stations, in each of which are installed four units, each consisting of a 100 H. P. type F. H. De La Vergne oil engine, direct-connected to a 6-in. by 18-in. National Transit Co. herring-bone-geared power pump with 8-in. suction and 6-in. discharge. The performance of one station equipment (three units) is given below..

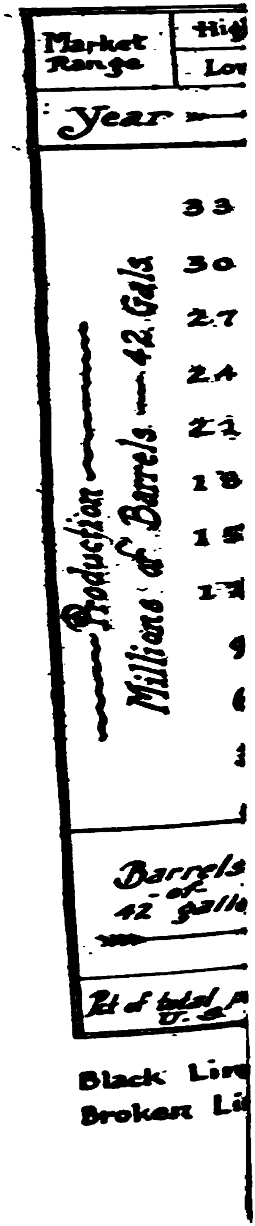
Oil pumped during 10 days, bbls.	140,000
Oil pumped per day, average, bbls.	14,000
Pressure maintained in line, pounds per sq. in.	700
Brake horse-power, average	196
Pump efficiency, estimated, per cent.	85
Fuel consumed by engines during 10 days, bbl.	65.8
Fuel consumed by engines per day, pounds	2,020
Brake horse-power hours per day $= 196 \times 24$	4,704
Fuel consumption per brake horse-power hour, pound	0.43
Foot-pound of work per day developed by the engines $= 196 \times 33{,}000 \times 24 \times 60$	9,320,000,000
Foot-pound of work per day in oil pumped $= 9{,}320{,}000{,}000 \times 0.85$ (85 per cent. efficiency)	7,900,000,000
B. T. U. in fuel consumed per day $= 2020 \times 18{,}000$	36,000,000
Foot-pound of work per 1,000,000 B. T. U.	217,000,000
Daily operating cost:	
Fuel oil: 6.58 bbls. at $1.50	$9.87
Lubricating oil: 2 gals. at $0.22	0.44
Cylinder oil: 1.6 gal. at $0.21	0.34
Attendance: Total salaries of 2 engineers, 2 assistant engineers, 1 chief engineer and 2 telegraph operators	41.50
	$52.15
Cost per brake horse-power hour ($52.15 ÷ 4704)	$0.011
Cost per bbl. of oil pumped ($52.15 ÷ 14,000)	0.0037
Bbls. of oil pumped per bbl. of fuel consumed (14,000 ÷ 6.58)	2,130

"In conclusion, it may be said that the comparatively small amount of power involved in pipe-line transportation lends itself admirably to the efficient use of the oil engine as a prime mover. And unless some other form of power can show better results in the immediate future, the oil engine bids fair to hold its present superiority as a means for the transportation of oil."

OIL WELLS.—Oil properties are unlike mining properties, where a certain amount of ore is mined each day, and that amount can be increased by putting more men to work. Very often the oil "comes in" with a rush at a high rate of production, which lasts for a number of days or months, diminishing gradually in daily output, however, as the underground pressure in the oil sand is released. As a result, the well makes a constantly reducing daily production, and oftentimes after a few months it becomes necessary to place tubing in the well and pump the oil from the sands. Some wells produce for many years, but often one-half of the well's total output will be obtained during the first year, and all the remaining years of the well's life are spent in getting out the other half of the total oil.

At some wells, as soon as the drill penetrates the oil sand, oil and gas in tremendous volumes are driven out the top. Often the well owner, not being prepared for such a condition, will not have sufficient tankage ready, and a large amount of the production will be lost.

Many oil wells are nearly a mile in depth. When speaking of a "barrel" in connection with crude oil, it is customary to understand that 42 gallons of the oil are referred to.


Market Range
Year
33
30
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Millions of Barrels — 42 Gals
Barrels of 42
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SECTION 4a

PETROLEUM CHEMISTRY AND OTHER DATA

PETROLEUM CHEMISTRY.—Petroleum is a highly complex mixture of hydrocarbons, in which the element carbon constitutes about 85 per cent. Some of the hydrocarbon molecules of petroleum are gases at ordinary temperatures, while others are liquid and others are solids.

In chemistry matter is considered to be made up of a large number of small particles called *molecules*. The molecules are also regarded as being made up of still smaller particles called atoms. The molecule is supposed to represent the smallest particle of matter capable of separate existence. Matter can then be classified with respect to its molecular structure.

If matter, as it occurs in nature, is split up into its component substances until it is no longer possible to further subdivide it, the resulting substances are called *elements*. The element is, therefore, the ultimate component of matter. Thus hydrogen alone can only produce hydrogen, and it is an element. Carbon alone can only produce carbon, and it is also an element. Altogether there are 75 elements. Typical elements are nitrogen, oxygen and hydrogen, carbon, sulphur, gold, silver, copper and tin. Thus it can be seen that these elements are found in the form of gases, solids and metals.

It has been demonstrated by scientific research, that the atoms composing the various elements will unite with the atoms forming other elements, in simple proportions, according to weight. The relative weights of the various elements have been worked out, using the weight of the element hydrogen as a basis. The relative weight of hydrogen is taken as one (1).

Some of the "*atomic weights*" of the various elements met with in the petroleum industry are given as follows:

Symbol	Name	Atomic weight
H	Hydrogen	1
O	Oxygen	16
C	Carbon	12
N	Nitrogen	14
S	Sulphur	32.1

In order to comprehend the fact that atoms unite to form molecules, it may be assumed that each atom sends out a radiating force, which draws the other atoms together. This attractive force can be called *chemical affinity*. The different elements have different chemical affinities; thus it has been found that carbon has four times the chemical affinity of hydrogen, so that four atoms of hydrogen can be attracted and held by one atom of carbon.

Valence is defined as the replacing power of an element, when measured in terms of the element hydrogen taken as unity, or one. Valence can be better understood if we imagine that each atom is a round piece of cork, and that radiating out from the corks are needles. For the element carbon there would be four needles and from the element hydrogen there would be one needle. We could stick four atoms of hydrogen onto the carbon atom, or cork. Thus carbon has a valence of four.

CHEMICAL STRUCTURES OF VARIOUS CRUDE PETROLEUMS

In a general way the composition of the oils obtained from the various fields in the world can be given as follows:

(*a*) Mid-Continent Field	Mixtures of paraffin and some of the other less important series of hydrocarbons.
(*b*) California	Olefin, naphthene and paraffin hydrocarbons.
(*c*) Appalachian Field	Paraffin hydrocarbons.
(*d*) Wyoming	Paraffin hydrocarbons.
(*e*) Illinois	Mixtures of olefin, paraffin, etc.
(*f*) Mexico	Mixtures of all kinds of hydrocarbons.

The *paraffin hydrocarbons* contain in each molecule twice as many, plus two, atoms of hydrogen as of carbon. The chemical formula would be:

Paraffin hydrocarbons .... $(C_nH_{2n}+_2)$

The *olefin hydrocarbons* contain only twice as many hydrogen atoms as carbon atoms. The chemical formula would be:

Olefin hydrocarbons .... (C_nH_{2n})

The olefins are termed unsaturated, and may under suitable conditions add hydrogen or other atoms.

The *naphthene hydrocarbons* predominate in California oils, Russian and Japanese oils. As in the case of the olefins, each member has twice as many hydrogen as carbon atoms. The characteristic formula is:

Naphthene hydrocarbons .... (C_nH_{2n})

In this series the value of $(_n)$ may be from 1 to 15.

NOTES ON CHEMICAL CHARACTERISTICS.—The light or most volatile constituents of all petroleum are largely composed of "paraffin" $(C_nH_{2n}+_2)$ hydrocarbons. They are "saturated" hydrocarbons, and are not acted upon by sulphuric acid (either concentrated or fuming). The "naphthenes," ring or cyclic compounds (C_nH_{2n}), are generally found as the heavy hydrocarbons of petroleum. They resist action by sulphuric acid. The ratio of their specific gravities to their distilling temperatures is higher than for paraffin compounds.

The "aromatic hydrocarbons," according to several authorities, are formed by decomposition at temperatures above 1000° Fahr. from paraffin and naphthene hydrocarbons (C_nH_{2n-6}).

The "olefines" (C_nH_{2n}), or "ethylenes," are "unsaturated hydrocarbons," commonly resulting from exposing oil to high temperatures. They are capable of taking up hydrogen. They can be removed from the aromatic, paraffin and naphthene compounds by treating with sulphuric acid (concentrated).

COMPOSITION OF VARIOUS CRUDE AND HEAVY OILS— The table following gives the composition of various oils:

COMPOSITION OF VARIOUS OILS

Source	Kind	Carbon, per cent.	Hydrogen, per cent.	Oxygen, per cent.	Specific gravity	Flash point, degrees	B.t.u. per pound
Pennsylvania......	Light	82.0	14.8	3.2	0.816	...	......
Pennsylvania......	Crude	84.9	13.7	1.4	0.938	...	20,730
West Virginia.....	Light	84.3	14.1	1.6	0.841	...	......
West Virginia.....	Heavy	83.5	13.3	3.2	0.873	...	......
West Virginia.....	Crude	86.6	12.9	0.5	.....	...	21,240
Virginia..........	Resid.	87.1	11.7	1.2	0.860	...	19,200
Texas............	Crude	85.7	11.0	3.31	0.945	244	19,240
Ohio............	Crude	80.2	17.1	2.7	0.887	...	21,600
California.........	Crude	84.0	12.7	1.2	.....	...	......
Canada	Crude	84.3	13.4	2.3	0.857	...	20,420
Wyoming.........	Crude	82.0	14.2	3.6	0.996	...	19,700
Baku (Russian)....	Light	86.3	13.6	0.1	0.884	...	......
East Gallicia......	...	82.2	12.1	5.7	0.870	...	......

BLOOM OR FLUORESCENCE.—This is believed to be due to the presence of pitchy material, or asphalt-like material, which is in a colloidal condition in the oil.

COLOR AND ODOR.—Generally distillates from petroleum contain sufficient foreign matter to give the oil an undesirable odor and a reddish to yellowish color. Sulphur compounds, in natural distillates, are one of the causes of odor, and a characteristic compound is hydrogen-sulphide. Cracked gasoline or light hydrocarbons generally have a disagreeable odor, although sulphur may be absent in any considerable quantity. Nitrogen compounds are thought to be chiefly the cause of color in petroleum products.

It was early found that kerosene could be decolorized and deodorized by sulphuric acid treatment. Sixty-six degrees Baumé sulphuric acid is ordinarily used. It reacts on the saturated compounds, the sulphur compounds and the nitrogenous compounds in the oil by forming substances which dissolve largely in sulphuric acid. The oil treated with the acid undergoes a shrinkage, which may vary from practically nothing up to 10 or 11 per cent., depending upon the character of the oil.

SPECIFIC HEAT OF PETROLEUM

SPECIFIC HEAT OF OIL.—The thermal capacity of a body or liquid can be defined as the amount or quantity of heat required to raise its temperature 1° F. The specific heat of a substance or liquid is the ratio of the quantity of heat required to raise the temperature of one pound of the substance 1° Fahr. to the quantity of heat required to raise the temperature of one pound of water 1° Fahr. from the temperature of the maximum density of water, which is 39.1° F.

The specific heat of an oil is, therefore, really a measure of its heat-absorbing property as compared with water. The subject of the value of thermal capacity of lubricating oils is one that has been but little investigated. It should, however, be given some attention, particularly in the case of forced-feed lubrication, in instances where the oil film is working under severe conditions and is required to remove frictional heat in considerable quantities.

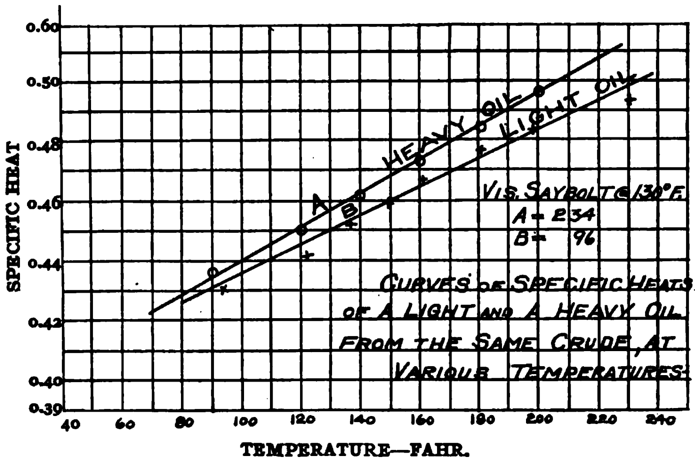


FIG. 1. SEC. 4a.—Curves of temperatures and specific heats of light and heavy engine oils.

The frictional heat developed in a bearing must be absorbed and carried away by the oil or radiated from the bearing to the air, or conducted off by the engine frame. Various claims have been made by manufacturers as to the merits of heavy and light oils with regard to their heat-absorbing qualities. The curves shown in Fig. 1, above, illustrate the effect of temperature increase upon the specific heats of two oils having widely different characteristics and viscosities. The curves show that the differences are very small, and may, therefore, be neglected.

Certain investigators have found that impurities lower the specific heats of petroleum oils to a considerable extent.

In general, according to several authorities, the specific heats of samples of crude petroleums obtained from various sources throughout the world varied from 0.500 to 0.400.

Messrs. Bacon and Hamor in their book on "The American Petroleum Industry," state as follows: "It would seem that there is no close agreement between specific heat and specific gravity. Pennsylvania oils stand at the head * * * It has been found that in the case of California petroleum as the asphalt content increases the specific heat decreases."

The following specific heats of oils are taken from various sources and authorities.

SPECIFIC HEATS OF CRUDE OILS, DETERMINED BY MAYBERRY AND GOLDSTEIN

Source	Specific gravity	Specific heat
Pennsylvania	.8095	.5000
Texas (Lucas Well)	.9200	.4315
Russian	.9079	.4355
Wyoming	.8816	.4323
California*	.9600	.3980
Texas	.9466	.4009
Ohio	.....	.4951
Commercial gasoline	.....	.5131

* NOTE. Average of twelve samples varies from .3999 to .5016.

HYGIENIC FACTORS

PETROLEUM POISONING.—Bacon and Hamor in their book, "The American Petroleum Industry," vol. ii, say with reference to petroleum poisoning: "The symptoms are as follows: The victim is seized with sudden weakness of the legs and dyspnœa. He may fall down in a coma and die of asphyxia on reëntering a non-ventilated, partially emptied reservoir. * * * In mild cases some of the workmen complain of vertigo, headache, nausea, bronchitis and mental depression, but others have a feeling of elation and rather like the intoxication. * * * *

"Chronic type: Chronic poisoning causes vertigo, fullness and throbbing of the head, cough, dyspnœa, anæmia, general nervousness, hallucinations and loss of memory. * * *

"The skin affections usually take the form of inflammation of the hair follicles (acne), eruptions, with characteristic formation of vesicles and pimples and pustules, which precede the deep-seated formation of ulcers, abscesses, etc."

PREVENTION.—All workmen who are in contact with petroleum, either in the refining processes or in the use of the resulting products, should observe the rule of frequent bathing. Water baths with hot water and the free use of soap are the best insurance against skin troubles. The overalls used by the workers should be frequently washed.

Workmen in manufacturing plants using petroleum, such as cutting oils, washing oils, etc., where the hands are constantly covered with the oil, should take particular care to frequently wash their hands with plenty of soap and water. One of the chief points attacked in these cases is between the fingers, and frequently the workman loses considerable time due to sore hands.

NOTE. See Cutting Oil Section.

SECTION 4b

SHALE OILS

OIL SHALES.—Oil shales are found in the United States in parts of Kentucky, Colorado, Utah, Nevada, Montana and California.

There are considerable quantities of oil shales found in Scotland, where the shale oil industry has reached large proportions. In Scotland the oil shales are mined in a manner somewhat similar to the mining of bituminous coal. Sometimes as much as 30 gallons of oil per ton are obtained from the Scotch shales.

Shale oil in its crude state is dark green to brownish in color. It has a specific gravity of 0.85 to 0.95. Its cold test is about 30° C.

Oil shales have been found and mined in Australia, New South Wales, France, England, Serbia, Canada, Tasmania, Austria-Hungary, Turkey, Brazil, Italy and Spain.

Various products, such as burning oils, paraffin wax, lubricating oils, gas oils and naphtha, have been obtained from Scotch oil. Investigators have reported that Scotch shale oil is of a paraffin base.

It is claimed by some authorities that lubricating oils made from Scotch shale crude oil do not show as rapid a decrease in viscosity as their temperature is increased as do many mineral lubricating oils.

Paraffin wax obtained from Scotch shale oils has been listed with melting points as high as 103° F.

Scotch shale lubricating oils have been found to have specific gravities of about 0.85 to 00.900.

TREATMENT OF OIL SHALE.—The cut of a retort for the destructive distillation of oil shale, as shown in Fig. 1, Sec. 4b, shows a retort furnace used by the American Shale Refining Company, of Denver, Colo., U. S. A., at their plant near De Beque, Colo. The furnace consists of four retort chambers, arranged alternately, to form a cylinder about 30 feet high and 12 feet in diameter. It has two air-tight steel tanks on top containing the crushed shale. This shale is fed automatically onto a revolving table in the top retort chamber, and is agitated while exposed to the heat. There is a similar table in each retort chamber, and the tables are turned by a main shaft, which extends from the base to the top chamber.

By repeating this process through several retort chambers and regulating the heat, it is estimated that when the shale is removed at the bottom by screw conveyors, 95 per cent. of the desired constituents have been extracted.

The gases are drawn off by means of a vacuum pump, which leads them to water-cooled condensers, where the oils are collected and run into storage tanks.

The process was described in the " Engineering and Mining Journal," of May 18, 1918, by F. A. Wadleigh.

Note. A paper read by Dr. David White, chief geologist of the United States Geological Survey, at the Motor Fuel Session of the Society of Automotive Engineers, in New York, February 6, 1919, embodied the following:

"Among the largest, if not the largest, deposits of oil shale in the world are those of northeastern Colorado, northeastern Utah, and southwestern Wyoming, mainly in what is known as the Uinta Basin. Rich beds of oil shale also occur in very limited areas in northeastern Nevada. Minor deposits, more conveniently located but for the most part leaner and less promising, are found in the Mississippi Valley and the Appalachian States. D. E. Winchester and A. R. Schultz, of the Geological Survey, have estimated that there are in Colorado, Utah, Wyoming and Nevada deposits of oil shale in thickness of 3 feet or more, and capable of yielding 25 gallons or more of oil per ton, sufficient to produce at least 75,000,000,000 barrels of oil.

FIG. 1. SEC. 4*b*.—Retort for the destructive distillation of oil-bearing shale. (Courtesy of Engineering and Mining Journal.)

"The oil is generated through the destructive distillation of the shale, and its character and composition depend largely on the processes employed. Rough dry or steam distillation tests produce distillates—essentially heavy petroleums—carrying both paraffin and asphalt with considerable nitrogen and yielding gasoline in an average of about 12 per cent. These rough tests indicate that the gasoline obtainable by distillation of these shales, even by simple methods, far exceeds in amount all the petroleum yet produced in the United States and may equal the remaining natural oil.

"The production of oil from these shales is still in the experimental stage, in which various methods are being tested. Much doubtless depends on the processes devised and adopted. It is possible that initial commercial success may be determined as much by a study of methods

and of the possible by-products and their values as by a further advance in oil prices. The technologic problems connected with the utilization of the oil shales are worthy of research by the best hydrocarbon engineers and chemists.

"Shale oil is the most natural, satisfactory and ample substitute for petroleum, and it is likely to come into the market as the production curve of the natural oil glides downward beyond the peak, if not sooner. It must be borne in mind, however, that in spite of the probably very rapid growth of the shale-oil industry beginning with the day that shale oil is produced profitably on a commercial scale, it will require several years to construct and put into operation the enormous plants necessary to treat the millions of tons of shale."

HISTORY OF SHALE OIL INDUSTRY.—(U. S. Bureau of Mines, Department of Interior, "Notes on Shale Oil Industry," by Messrs. Gabin, Hill and Perdew): Destructive distillation of oil shale in Scotland was first practised on a commercial scale in 1860, and increased gradually, so that in 1917 the production was 3,116,529 long tons. The distillation of bituminous shale has also been an industry in France since 1850. A small amount of oil has been produced from shales in New South Wales, and the shales are said to average from three to three and one-half times as much oil per ton as the Scotch shales. In the States of Colorado, Utah, Montana, Nevada and California, there are large deposits of rich shale, and some shale oil has been and is being produced. While there are several plants throughout the country of an experimental and demonstration nature, there has not been any considerable commercial development.

OIL SHALE AND ITS PROPERTIES.—Oil shale is found in beds, or strata, running from a few inches to several feet thick. The yield of oil ranges from practically nothing to ninety gallons or more a ton. According to the Bureau of Mines paper, as quoted, usually the oil does not exist as such in the shale, but is produced by the destructive distillation of complex organic compounds in the shale, these compounds probably being of vegetable origin, and destructive distillation; that is, heating in the absence of air decomposes this organic matter, yielding hydrocarbon oils and permanent gases. Oil shale also contains varying quantities of nitrogenous compounds, which, under the action of heat, decompose into ammonia and other nitrogenous bases, including pyridines and pyrrols. Some laboratory tests on certain layers of shale usually too thin to mine commercially, indicated a yield upwards of ninety gallons of oil per ton, while tests on more extensive deposits of several feet thickness indicated one barrel (42 gallons) per ton. The quantity and quality of the oil obtainable from a given shale depend to a large extent on the methods used in obtaining the oil, the types of retort, the rate of heating, removal of vapors, etc.

The ash content of American oil shales of commercial importance ranges from 45 to 80 per cent., the average being 60 per cent., and, therefore, this high ash percentage would indicate that it is improbable that shale can be burned directly as fuel from a practical standpoint.

PRACTICE IN SCOTLAND.—(U. S. Bureau of Mines, Department of Interior, "Notes on Oil Shale Industry," by Messrs. Gabin, Hill and

Perdew): Scotch shales are mined underground, similar to coal mining, the roof being supported with pillars, and usually about 25 per cent. of the shale is left underground in mined-out workings. The shale is carried to the surface, transferred to breakers, consisting of two large tooth rolls, and broken into pieces not larger than six inches square, then transferred by tramways to hoppers at the tops of the retorts. These hoppers, closed at the top with a lid, hold several hours' supply of shale, a seal being made around the rim of the cover with moist sand. The shale feeds by gravity into the retorts, which are vertical and tapered, running from about 2 feet in diameter at the top to 3 feet at the bottom, to aid the general movement of shale. The upper part of the retort is one-piece iron casting about 12 feet high, and here the bulk of the oil distils. The vapors and permanent gases are removed under slight suction through a pipe, forming a part of the top casting. The lower part of the retort is built of one tier of special shaped firebrick and averages about 18 feet high. Here the shale is heated to its maximum temperature of from 1700° to 1800° F. The ammonia and water gas are formed here, through the action of steam on the red-hot carbon and nitrogenous material remaining in the shale. From the retort the shale is discharged into a steel hopper, which has a capacity of several hours' output of the " spent " shale. Exhaust steam is admitted to the hopper holding the hot spent shale, and serves to cool the shale in the bottom of the retort, to form water gas from the fixed carbon, to carry away heat from the spent shale into the retort, for sweeping the oil vapors out of the retort, and for improving the transfer of the heat from the walls of the retort to the centre of the charge. The retorts are heated by permanent gases obtained from the destructive distillation of the shale, and the retorts are set usually four together to a common furnace, and sixteen of these sets of four make up a bench of thirty-two retorts long and two wide. In Scotland the capacity of a retort per day is about four long tons. The spent shale is dumped into huge heaps, called " bings." It was found that in a Scotch shale that yielded about 27 gallons or more of oil per short ton, there was a sufficient yield of fixed gases to heat the retort.

From the retort the oil vapors, gases and steam are led to a common header, and then through an air-cooled vertical condenser, and the oil and water vapors from the condensers are run into separators, when the ammonia water is separated from the oil, while the non-condensible gases have their light oils and ammonia removed by passing through scrubbers, and are then used as fuel for heating the retort. The crude shale oil after separation from the ammonia water is sent to the crude stills, where it is divided into various fractions by distillation, and the oils from the scrubber above described are also distilled, and the light oils obtained are added to the corresponding distillates from the crude shale oil. The refining of the shale oil is similar to petroleum refining, although the operation has been found to be more complicated and expensive.

Shale oil is different from crude petroleum, in that it contains certain organic compounds that give it a bad odor, and these organic compounds must be removed before marketing the product.

SHALE OIL CHARACTERISTICS.—Shale oil contains more unsaturated constituents than petroleum, and requires careful refining and the

removal of unsaturated products and compounds which give it a bad odor. This is effected by several distillations and acid and alkali treatments, which give a high refining loss, which averages about 25 per cent. in Scotland, which compares with 7 per cent. in the refining of petroleum.

The Scottish shale yields at the present time on the average about 24½ U. S. gallons of crude oil and about 35.7 pounds of ammonium sulphate per short ton. The yield of gas per short ton of shale varies considerably, but averages about 9800 cubic feet, with a heating value of about 240 B. T. U. per cubic foot (U. S. Bureau of Mines publication).

PRODUCTS OBTAINED FROM CRUDE SHALE OIL.—(U. S. Bureau of Mines publication): The products obtained by the refining of crude shale oil in Scotland include motor gasoline, illuminating oils, gas and fuel oils, lubricating oils, paraffin wax and coke. The yield of these products varies, depending upon the nature of the shale and the retorting and refining conditions. Three grades of lubricating oil are generally made, none of them being suitable for steam cylinders, internal combustion engines or heavy bearings. The products obtained in the refining of crude shale in one of the largest Scottish works, according to the U. S. Bureau of Mines publication, are:

Naphtha (including scrubber naphtha)	9.9%	450 end point
Burning oil	24.7%	
Gas and fuel oil	24.4%	
Lubricating oil	6.6%	
Wax	9.5%	
Loss (including still coke 2%)	24.9%	

NOTES ON AMERICAN SHALE OIL.—(Report of investigators to Governor Shoup, of Colorado. Extracted through *National Petroleum News*, vol. ii, No. 47, November 19, 1919):

It is reported that fully 30 processes for retorting oil shales have come to the attention of the Bureau of Mines, most of them using modification of the retorts used with success in Scotland. None of the different retorts in this country have yet been tried on a commercial scale. The American shales are richer in oil and poorer in nitrogen than the Scotch shales, and it may be that the best commercial results will be obtained by sacrificing complete extraction of oil and ammonium sulphate for increased capacity. In the opinion of many who are well qualified to judge, those processes which are intended to distil shale without steam or distil and fractionate in the same retort can never meet with success.

Although we must refer to the Scotch plants as our only criterion, it must be remembered that their processes have undergone no important changes for the last 25 or 30 years. Many of their methods are old-fashioned and cumbersome, particularly the huge air-cooled condensers. Several competent American technologists have made extensive laboratory experiments from which it appears that improved methods of retorting and refining will make it possible to obtain much better results than are now obtained in Scotland. They claim that refining losses can be kept below 5 per cent. They also claim that a high-grade lubricating oil, suitable for use in internal combustion engines, can be made if, from a commercial point of view, it is desired to do so. Plans are now being

made to try some of these new processes on a commercial scale. If they are successful it will result in a big impetus to the shale-oil industry in this country.

Although there are about 2000 square miles of oil-shale lands in Colorado, there is a comparatively small area so situated as to be suitable for exploitation at the present time. Transportation and an abundant water supply are paramount considerations. Considering these factors, the shale outcrops on the north side of the valley of Grand River between the towns of Grand Valley and DeBeque offer the most favorable point for attack.

They are close enough to the main line of the Denver and Rio Grande Railroad to permit the plant to be built either adjacent to it or on a short spur track, and Grand River contains an abundant supply of water. Living conditions are good, and there should be no difficulty in obtaining labor. If it appears desirable to erect a sulphuric acid plant in connection with the refinery, as some investigators suggest, raw material in the shape of pyrite can be obtained from Red Cliff or Leadville, which are not far away. Deposits of native sulphur have been reported from Delta County which might possibly be used instead of the pyrite. The disposal of the spent shale could be taken care of by gravity if the plant were located above the bottom of the valley on the lower slopes of the cliffs.

The mines must necessarily be near the top of the cliffs, 2000 feet or more above Grand River Valley. The retorting and refining plants must be near the railroad and water supply; that is, at the bottom of the cliffs. Consequently some means of transportation between mine and plant must be provided. This will undoubtedly be either a surface tram or an aerial tram. The former will probably be used, as for a large capacity it is cheaper to install and to operate than the latter. The shale, shoveled into the cars at the working face, would, with a surface tram, be hauled from the mine to the head of the tram by the same locomotive that brought them to the surface, lowered by gravity to the level of the plant, and dumped into the crusher bins. With an aerial tram the mine cars would have to be dumped into bins at the upper terminal, loaded into tram-buckets, dumped into the bins at the lower terminal, and, if it were not possible to locate the terminal at the crusher bins, loaded into other cars and trammed to the crusher bins.

If, as has been suggested, the plant were located on the lower slopes of the cliff, it should be possible to run the crushed shale from the storage bins below the crushers to the retorts and also to dispose of the spent shale by gravity. The refining plant would be below the retorts and might be at a considerable distance from them. It is probable, however, that the refinery will be located near the retorts, as the crude shale oil is too viscous to be conveyed through pipes like crude petroleum.

The most economical arrangement of the retorting and refining plant with relation to the mine and the railroad in any particular case calls for a high degree of engineering skill. The cheapness with which any plant can be operated is very largely dependent not only on the convenience of its internal arrangement, but also on the ease with which the raw material is received and the waste and finished products are sent out. Ample storage facilities must be provided for the finished products from which they

can be conveniently loaded into railroad cars. It is also extremely important that plans be made for the disposal of the vast quantities of spent shale at the least possible cost.

Near the tops of the cliffs, in the area under discussion, there are said to be one or more beds of shale from five to eight feet in thickness which yield a barrel (42 gallons) or more of oil per ton and which are fairly permanent in thickness and oil content over considerable areas. It is reasonable to suppose that one of these beds will be mined for the first commercial operations. Above them are several hundred feet of strata containing various, and for the most part smaller, percentages of oil. It is probable that these thicker, leaner beds will be worked after the industry is well established and the lowest grade of shale that can be worked at a profit fully determined by commercial operations.

Some preliminary mining may be carried on by quarrying or open-cut methods, but when it comes to making a steady production of 1000 tons or more per day it will be necessary to resort to underground mining. The methods employed will be nearly, if not exactly, those employed in mining coal. As no mining of any consequence has yet been attempted, it is impossible to tell in detail what particular methods will be found best suited for extracting the shale. In mining coal, unless it is to be used for making coke, the aim is always to extract it in as large lumps as possible with a minimum amount of fines; for this reason, the coal is usually undercut and then broken down with the least possible amount of explosive. There will be no such restriction in mining the shale as it will all have to be crushed before going to the retorts anyway. It will, therefore, be mined with the idea of breaking it all to pieces small enough to go into whatever form of crusher is adopted. The fact that the beds in Colorado are all practically flat will make the mining easier than in the pitching and contorted beds of Scotland.

There are two general methods of mining that may be applicable to the shale beds which are likely to be mined first. One is known as longwall and provides for the extraction of all the material in the bed. Longwall advancing could not be used, as there would be little or no waste with which to support the roof. Longwall retreating, in which the adits are driven to the limits of the area to be mined before production is commenced, might be practicable if there were no necessity of saving the beds above the one being worked. It is doubtful if any longwall method can be practised in this case, as it involves allowing the roof to cave in and would probably result in destroying beds above which will undoubtedly prove of value in years to come, and should, therefore, be preserved.

The other method, known as room-and-pillar, is that commonly employed in coal mining in this State. It consists in driving adits or "entries" from which rooms are "turned" at suitable intervals. Pillars of sufficient size to support the roof are left along the entries and between the rooms. The percentage of shale recovered by this method cannot be determined until sufficient work has been done to determine the size of pillars necessary to preserve the workings.

The physical character of the oil shale is such that it cannot be drilled to advantage with percussion drills of any sort. It can, however, be drilled with coal-drilling machines of the Hardscog, Thompson & John-

son or Howell types. The best explosive for breaking it has not been determined, but it seems probable that some of the low-grade ammonia dynamites, known in coal-mining parlance as permissible explosives, will be found most suitable.

In order to mine 1000 or more tons per day the mine must be opened systematically and according to some carefully considered plan which will insure the development work being kept well ahead of the extraction and provide for the health and safety of the miners. Mechanical ventilation will be necessary and proper precautions must be taken to guard against gas and dust explosions. Before the work has progressed very far mechanical haulage of some kind will be necessary.

MINING COSTS.—Until mining on a commercial scale has actually been practised it will be impossible to say definitely what it will cost. From the information at present available, and from coal-mining experience, it appears that, after a mine is opened and equipped to produce 1000 tons per day, the shale can be broken and delivered to the surface for $1 per ton, including the cost of the necessary development work. To this must be added the cost of upkeep and additions and repairs to equipment, which will be about 25 cents. This gives a total mining cost of $1.25. It is possible that this may be reduced, slightly, in practice; it is also possible that unforeseen conditions may increase it materially.

The equipment of the mine will include tools for mining track, cars, locomotives, ventilating fans, shops and shop equipment. For a mine producing 1000 tons per day the equipment will cost about $50,000.

In addition to the cost of equipment, the cost of opening the mine to put it in shape to produce the required tonnage, assumed as 1000 tons per day, must be considered. This will depend on the method employed and on other conditions not yet fully understood. In any case, the preliminary mining, incident to the opening, will be much more expensive than the regular operations after full production is attained. The cost of opening the mine is roughly estimated at $50,000.

The cost of delivering the shale to the upper terminal of the tram, assuming that the terminal is reasonably near the entrance of the mine, will be included in the mining cost. Lowering the shale to the crushing plant over a rail tram, including maintenance charges for the tram, should not exceed 5 cents per ton. The cost of building the tramway will depend on the length and type used. It may be as little as $5000 or as much as $25,000.

If the shale has to be transported from the lower terminal of the tram to the crushing plant, there will be an additional cost to cover the transportation. This should not amount to more than a few cents per ton.

CRUSHING.—Until experiments on a commercial scale have been tried it is impossible to say what form of crusher will be found best adapted to the Colorado shale. Some investigators state that gyratory crushers have been found satisfactory, others that the Scotch toothed rolls are the only suitable machines. Nearly all are agreed that jaw crushers cannot be used to advantage.

The cost of crushing the run-of-mine shale to pieces not larger than 2 or 2½ inches in diameter will probably not exceed 5 cents per ton. The cost of the crushing plant cannot be accurately determined until the type

of crusher most suitable for the shale has been worked out by large scale experiments. It seems probable that $10,000 should cover it.

The retorting operations will yield, in all probability, sufficient gas, in addition to that necessary to heat the retorts, to furnish fuel for boilers which will generate the power necessary in the plant. If there is not sufficient gas generated in the regular retorts, one or more of them can be run as a gas producer to augment the regular supply. The power for the haulage system, ventilating fans and shops at the mines will doubtless be transmitted in the form of electricity.

The retorting and refining operations will require, according to the best authorities, about one ton of water for each ton of shale treated. A 1000-ton plant on this basis will need 240,000 gallons of water per day. While this might be obtained from one of the creeks by buying up ranches to secure the water rights, it seems more likely that it will be pumped from Grand River, electric power being transmitted from the plant to the pumps.

RETORTING AND REFINING.—The method or methods to be used in manufacturing the finished products from the raw shale constitute the most vital part of the oil-shale industry. Many investigators have devised retorting processes, which, according to their reports, show encouraging results in the laboratory. None has yet been demonstrated on a commercial scale, and until this is done no reliable estimates of costs can be given. Various estimates of the cost of a 1000-ton retorting plant have been made varying from $300,000 to $2,500,000. The larger estimates are those of the men who have had the most experience. They include all the necessary apparatus for making sulphuric acid and ammonium sulphate. The Scotch retorts have a rather small capacity, and hence a plant to treat 1000 tons per day requires a larger number of them. Many investigators believe that their various devices will enable them to get greater capacity than is possible in the Scotch practice, and, consequently, that they can use smaller plants, which can be erected for less money. Until commercial operations are established the practicability of the various processes, as well as the cost of erection and operation of plants, must remain indeterminate.

A well-known petroleum engineer and chemist says: "Careful estimates for a complete 1500-ton Scotch type plant, to be erected on this side, were a trifle over $1500 per ton day; at the present time this would cost 30 per cent. more, or, say, $2000 per ton. Recently a 1000-ton plant for Colorado was figured at $1200 per ton. Both were of the continuous vertical type, with regulation methods of oil distillation and ammonia recovery; more modern types, both in the retort end as well as the stilling end, can be erected for $800 to $1000 per ton for plants of 1000 tons capacity upward, if on a railroad and under normal conditions. A pre-war cost of refining, including recovering the ammonium sulphate, was 62 cents per ton with sulphuric acid at $6 per ton, while retorting cost 40 cents. To-day this cost is $1.25 and 70 cents, respectively; add to these the cost of mining or getting the shale plus general charges and you have a basal figure of what it should cost to recover the prime products."

In the Colorado shale field there will probably be no market for the crude shale oil—it will have to be refined before it has any market value.

Just what products will be made is at present indeterminate, because it is not yet certain what percentage of gasoline, lubricating oils and so on can be produced to the best advantage.

There should be some market for ammonium sulphate in Colorado and neighboring States. It is worth about $80 per ton, wholesale, at present.

BY-PRODUCTS.—The Scotch shale-oil producers have a well-established market for their principal products, for which reason, probably, they have paid little or no attention to possible by-products. While it is possible that by-products may be manufactured commercially from American shales, which will add materially to their value, it is not probable that this can be done during the early stages of the industry. Experimenters have produced in their laboratories many different substances from shale oil, such as dyes, high explosives and rubber substitutes, but it is most unlikely that the manufacture of such products on a commercial scale will be undertaken until the profitable production of gasoline, oils and ammonium sulphate is firmly established.

The spent shale contains a small amount, less than 1 per cent., of soluble potash. Under present conditions this could not be extracted at a profit, and, therefore, it cannot be regarded as a valuable constituent of the Colorado oil shales. In some places the shales contain appreciable amounts of gold, but the quantity is too small and its occurrence too irregular for it to have any commercial significance.

The difficulties that are likely to be encountered in marketing oil-shale products must be given consideration. The petroleum industry of this country, established for many years, has developed an extensive and efficient system of marketing its products. Before the shale-oil products can be of commercial importance it may be necessary to carry on a campaign of education in order to convince the public that such products can be used with the same degree of satisfaction as those obtained from petroleum.

Until the shale-oil industry has assumed large proportions it must depend upon local markets under the local competitive conditions that prevail during that period. At the present time the chief competition will be from products obtained from the oils of the Wyoming fields, which marketed over 12,000,000 barrels of high-grade crude oil in 1918, selling at $1.50 to $1.80 a barrel at the well. The oil-shale plants in Scotland are located very favorably, for they are near the two largest cities of Scotland and compete with petroleum products that must be imported from the United States and other foreign countries.

The Scotch oil-shale companies have built up the marketing end of their business along the same lines as those followed by the large petroleum companies in this country. They own their own tank cars, tank wagons and storage tanks. An oil-shale company would have to have ample storage capacity for its products because the output would be steady and continuous, the demand variable. The large oil companies have elaborate and efficient systems of distributing their products in the territory adjacent to the Colorado shale deposits, and these must be taken into consideration in connection with the disposal of the shale-oil products. It may be possible to sell at wholesale to the companies already in the field. If not, it would be necessary to build up and establish a market in the face of the hardest sort of competition.

YIELD OF OIL IN SHALES.—The yield of oil varies greatly with the different beds. Under the best methods of treatment thus far devised, a maximum yield of about 100 gallons of oil per ton of shale has been obtained and 60 to 70 gallons are not uncommon. There are large quantities of shale which will give an average of 50 gallons to the ton, but 40 gallons may be considered a very fair yield. This is a much higher amount than is obtained from the shales of Scotland, which have supported a prosperous industry for over a half century. The Scottish shales, however, give a greater amount of ammonia for ammonium sulphate than do those from Colorado. The oil yield of the Colorado shales is larger than that of the Wyoming shales, but is about equal to that of the Utah shales. Field tests do not reveal the maximum yield of oil from the shale because material from the weathered outcrop is generally used and because the apparatus used will not extract the full amount of oil. Weathered shale does not have as high a yield as unaltered material.

DATA ON COLORADO SHALE.—(*Petroleum Age*, Vol. 7, No. 4): "It is estimated that the total deposits of shale in Colorado alone amounts to 38,000,000,000 tons, and allowing 60 per cent. recovery, the shale available for mining and treatment will total over 23,000,000,000 tons, and a barrel of oil to a ton would yield 23,000,000,000 barrels from Colorado shale alone. It is estimated that the petroleum reserve of the United States amounts to less than 80 barrels per person; the probable per capita supply from shale in Colorado alone amounts to 210 barrels per person. There are about 252,000 oil wells in this country, with an average daily production of less than 5 barrels per well. If 200 oil-shale plants were operating, each treating 2000 tons of rock daily, there would be an annual production of about 120,000,000 barrels of oil, or, the equivalent of the petroleum output of nearly one-third of our oil-producing wells."

SECTION 4c

REFINING OF PETROLEUM AND MANUFACTURE OF PRODUCTS

PETROLEUM REFINING

PETROLEUM REFINING.—The subject of the refining of petroleum is not only interesting in itself, but a rough knowledge of the subject is essential to an understanding of the values and properties of the various petroleum lubricants.

Petroleum is a mixture of numerous hydrocarbons, each having a different boiling-point and gravity. When heat is applied to the crude and its temperature is raised, the various hydrocarbons distil or vaporize, as their respective boiling-points are reached. By condensing these vapors and collecting them in different tanks, the various products of petroleum can be separated.

GENERAL OUTLINE OF THE REFINING OF A TYPICAL CRUDE.—Each refiner has methods of his own, which he uses in handling the particular crude with which his refinery is supplied, and each crude requires special treatment to meet its individual requirements. It would not be possible to describe in detail the numerous methods of refining the different crudes, but by selecting a typical crude and outlining the processes of refining it, a general idea may be obtained of the refining of all crudes; for the principle of heating, vaporizing, condensing and purifying is the same for all petroleum refinement.

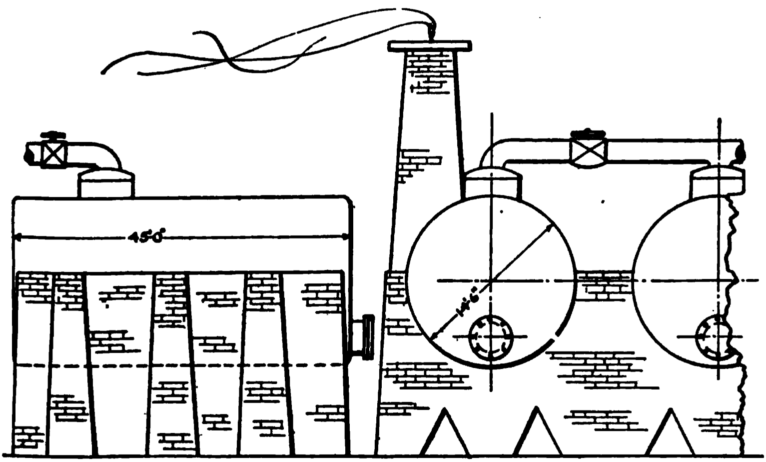
OUTLINE OF THE REFINING OF A TYPICAL CRUDE.—The crude is usually brought to the refinery in pipe lines, which are laid a few feet under ground and which range in size from 3 inches to 8 inches in diameter. At intervals along the line pumping stations are located, which place the oil under pressure. For moving the oil 60 miles, the pressure required in one case was a thousand (1000) pounds per square inch, and the oil issued from a pipe at a pressure of about 25 pounds.

A close check of the quantities pumped and received is kept at both ends, so that any leaks in the line may be quickly detected. A peculiarity of leaking oil is that it seeps upward to the surface of the ground, just opposite to water, and can thus be located easily. The crude is run into huge storage tanks and allowed to settle. It is then pumped to the stills.

STILLS

THE CYLINDRICAL STILL.—The old-style cylindrical still is composed of a cylindrical tank, of about 45 feet in length and 14½ feet in diameter. It is erected with its long dimension horiztontal, with a furnace compartment bricked in below the lower part of the shell. The upper part is left exposed to the weather.

There is a dome at the centre of the top, through which the vapors are allowed to escape from the still. These vapors are then passed through a cooling worm, where they are condensed. The condensed vapors in liquid form are run to the "cut house," where, by means of taking the gravity and color tests, the various divisions and cuts are made and the oils are run to different tanks as required. Fig. 1, Sec. 4c, shows the general form of a cylindrical still.



CAPACITY 1150 BBLS.

FIG. 1. SEC. 4c.—Crude stills.

THE TOWER STILL.—This type of improved still is intended for the distillation of petroleum (in the form of an undistilled residue), to obtain a wide range of products in the same run; the distillation being carried, at least in part, at the high temperatures necessary to evaporate hydrocarbons with boiling-points above 600° F., or above the commencement of "cracking" when the temperature is below 600° F

This type of still makes it possible to secure the early runnings of the distillate from a "charge of oil" in a purer state than is possible with the ordinary still.

Petroleum is distilled in "batches." With the usual type of still it is customary, before opening it for cleaning, to admit free steam to remove the remaining hydrocarbon vapors. These vapors are carried by the steam into the condensers, and remain there until the early runnings of distillate from the next charge dissolve them. This is objectionable, as

these vapors are different in color, gravity, etc., from the light vapors dissolving them, and thus the early distillate is impaired.

Provision is made in the Tower Still to discharge the mingled steam and vapors through a side passage, which is designed for that purpose and which leads to a special condenser, so that they do not impair the early distillate of the succeeding run.

The so-called Tower Still Apparatus, which is covered by numerous patents, may be described as follows, by referring to Fig. 2, Sec. 4c:

A horizontal still (1) is shown, which is heated by fires beneath and is well jacketed against heat loss. A pipe (2) is supplied for filling the still with oil. The pipe (4) carries away the vapors, and is connected with an upright pipe (3), which is provided with a removable cover (5). The pipe (3) receives the pipe (4) through a side opening, and below this opening is a valve (6). There is another side opening below this valve, which receives pipe (7), equipped with a valve (8). When running, (8) is closed and (6) opened; when the still is "steamed out," (8) is opened and (6) closed.

The pipe (7) is equipped with a safety valve. Steam for "steaming out" the still is introduced through the pipe (*A*).

The vapor outlet (4) leads the distilled vapors to the partial condenser (9), entering it at the space (10), which is below the grate (11). Above the grate (11) are placed a number of cobble stones (12), which are surrounded by a non-conducting heat jacket.

Above the stones (12) is a perforated plate, into which are tapped the tubes (13). These tubes, each one of which is usually equipped with a small flap valve, are enclosed in a casing or shell which fits around the header (14). This casing is provided with several air inlets at the lower part, as shown at (15). These air inlets admit more or less air as desired, the heat given off by the tubes producing a flow upward around the tubes and out at the top. The vapor outlet of condenser (9) is connected by the pipe (16) to the inlet of the condenser (17). The two partial condensers (9) and (17) have their condensed distillate outlets connected through U traps, with valved draw-off pipes, which are led to cooling worms. "Runbacks" (21) are provided for the two condensers, and are used to return any of the condensed distillate to the still, as desired.

The still (1) usually takes about 1000 barrels to 1200 barrels for one charge, and it is heated gradually by fires until the contents of the still have become dry, or nearly so, "wax tailings"* (10° B.) usually coming over last.

During the first part of the run the condensate formed in condenser 9 is returned to the still, through the runback, until the oil in distillation has attained a temperature of about 700° F.

The runback is then closed and the distillate from this condenser is collected through the draw-offs.

The condensed distillate pipes from the partial condensers are equipped with cooling worms and lead into troughs, mounted on turrets, which can be revolved so as to direct the streams of distillate to various tanks as desired. The building containing the troughs is called the "cut house."

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* See index.

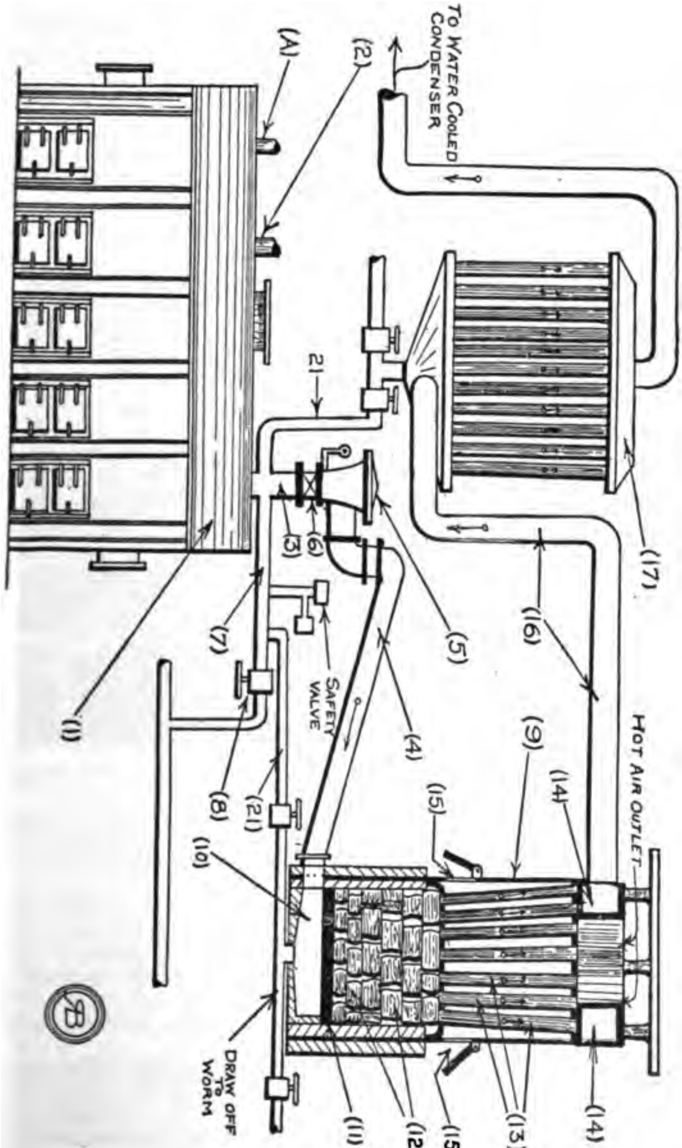

FIG. 2. SEC. 4c.—Outline of tower still.

As shown in Fig. 3, Sec. 4c). The ends of the pipes from the condensers are equipped with " boxes " having glass fronts, so that the color of the distillate may be easily watched.

Another advantage offered by the Tower Still over the old type of cylindrical still may be pointed out as follows:

With the old type of still, the refining process was carried to a certain point, and it was then necessary to pump the residue from the crude still, at high temperatures, allow it to cool and settle, and then after several days it was pumped to the " Tar Stills," where the refinement was completed.

A " Tar Still " holds about 250 barrels, and it is necessary to *reheat* the charge to the point where the refinement was stopped in the cylindrical

FIG. 3. SEC. 4c.—View in a cut or receiving house, showing streams of oil flowing into the cages from whence they are directed to separate tanks according to their grade.

still before the residue in the " Tar Still " will again give off the desired vapors. This process requires a lot of extra fuel, and is, therefore, more expensive than the continuous Tower Still.

The upkeep of the " Tar Still " is high, because it requires frequent new bottoms, a very good still averaging only about 100 runs before burning out, while with the Tower Still it is possible to obtain as many as, or more than, 500 runs without exhausting the life of the bottom.

The Tower Still is very flexible, as the distillate from any part of the condensers can be run back for redistillation into the still without interfering with the other distillates.

Crude stills are run at low pressures, the safety valves being set at about 1½ pounds per square inch.

REFINING METHODS

METHODS OF REFINING.—There are two methods of refining crude petroleum, known as: Running to coke or dryness and running to cylinder stock. Nearly all Appalachian Crude is run to cylinder stock.

(See Frontispiece for chart showing typical refining operations.)

CRACKING PROCESS

RUNNING TO COKE.—The process of refining known as "running to coke" consists in carrying the distillation of the crude oil to dryness.

The crude is run into a still of the Tower type or plain cylindrical type, both of which have been described. The distillation of the charge is carried on until about 50 per cent. of the oil has been distilled. These distillates are known as the "natural oils." When the distillates become too heavy or too dark in color to produce burning oil, the residue in the still is "cracked." (See Fig. 4, Sec. 4c.)

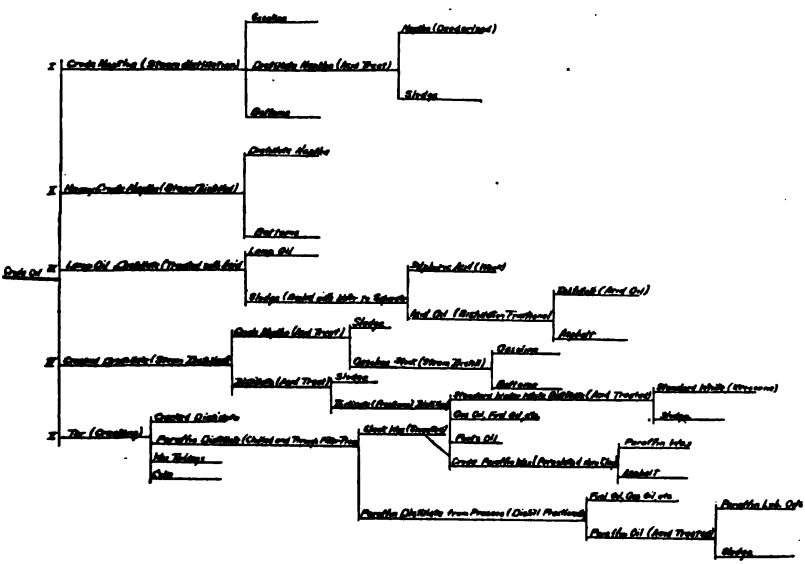

FIG. 4. SEC. 4c.—Mid-continent crude, cracking distillation.

THE "CRACKING PROCESS."—In carrying out this process, the fires are slackened and the top of the still is allowed to cool rapidly. The heavy vapors now coming from the oil are at a temperature of about 650° F. These vapors rise and strike against the top of the still, which is colder than their condensing temperature, and as a result they are condensed and fall back into the hot liquid below. This liquid is at a higher temperature than the normal boiling-points of the condensed liquids, and as a result the particles, falling back into this hot liquid, are immediately redistilled, resulting in an increase in the percentage of the lower boiling-point distillates, composing the naphthas and benzenes.

The "cracking temperature" of the vapors at the start is about 650° F., and by the time the cracking is finished it is usually between 700° and 750° F.

CRACKING, EFFECT ON LUBRICATING OIL.—When petroleum is cracked by heat, the paraffin hydrocarbons are decomposed into lighter hydrocarbons, and the lubricating hydrocarbons which remain in the cracked oil are, therefore, not paraffin, but chiefly consist of naphthenes and aromatics.

CRACKING, CHEMICAL NATURE OF.—The property generally known as "cracking" refers to the characteristic of heavy petroleum decomposing into hydrocarbons of lower molecular weight by heating, and the chemical reactions involved are not entirely clear. Crude oil that is subject to fire distillation allows the light products present in the oil to distil off without change, up to a temperature of about 300° C., these including both the gasoline and the kerosene. When this temperature is passed, the hydrocarbons undergo a partial decomposition, and some light products are distilled along with the heavy products.

There are a number of cracking processes and various patents. The cracking may be carried on in the vapor phase, at atmospheric pressure, or with increased pressure. The cracking may be carried on in the liquid phase, involving distillation at either atmospheric pressure or above atmospheric pressure, such as the Burton process, or at a very high pressure. Also, there may be cracking in the liquid phase without distillation and with high pressure, either without vapor space, for equilibrium, as in the continuous processes, or with vapor space, the latter being either intermittent or continuous.

Considerable quantities of cracked gasoline now on the market are made by the Burton process, and it is claimed that 63 1/2 per cent. of the original charge of oil is converted into gasoline under the Burton patents. (Patent 1,105,961.) The Burton process is described in U. S. Patent No. 1,049,667. In general, the operation of the Burton process is described as follows: Stills that have a capacity of 200 barrels each have heavy horizontal steel cylinders, thoroughly insulated with asbestos. From the top of the still is a long runback, which is exposed to the air, which returns for cracking any undecomposed oil. A pressure of 85 pounds to the square inch is maintained on the stills, the runback and the condenser. The oil is heated to a temperature of about 750° F. The stills are charged every 48 hours. * * *

The original Burton claims, as covered in Patent 1,049,667, filed July 3, 1912, and issued January 7, 1917, are as follows:

"1. The method of treating the liquid portion of the paraffin series of petroleum distillation, having a boiling upward of 500° F., to obtain therefrom low boiling-point products of the same series, consists in distilling at a temperature of from 650° to about 860° F. The volatile constituents of said liquid conducting off and condensing said constituents and maintaining a pressure of from 4 to about 5 atmospheres on said liquid of said vapors throughout their course to and while undergoing condensation.

"2. The method of treating the volatile portions of paraffin series of petroleum distillation having a boiling-point of upwards of 500° F., to obtain therefrom low boiling-point products of the same series, which consists in distilling off at a temperature of about 650° to 850° F. the volatile constituents of said liquid, conducting off and condensing said constituents, maintaining a pressure of about from 4 to 5 atmospheres on said liquid of said vapors throughout their course to and while undergoing condensation, and releasing from time to time the products of gas from the product of condensation."

SPECIAL CRACKING PROCESSES.—There are a number of cracking processes that have been developed. Some of the prominent ones are the Burton process, the Hall process, the Cross process, the McAfee process, the Rittman process, etc.

In the Burton process about 60 per cent. of the charge put into the still is distilled off, the vapors being condensed under pressure. The product obtained is called pressure distillate. This distillate is then fire distilled, and a crude, cracked naphtha obtained. This is usually blended with a straight-run naphtha and the mixture refined by chemical treatment and steam distillation.

In the Rittman process, the vaporized oil is carried downward, under pressure, through vertical tubes of about 12 inches in diameter and condensation usually effected at atmospheric pressure. The material used is usually kerosene distillate or fuel-oil distillate.

Messrs. Bacon, Brooks, and Clark have developed and patented a new cracking process (March, 1920), which claims a low cost of installation, a possible 80 per cent. recovery of gasoline against about 40 per cent. with the Burton process, an elimination of the carbon trouble common to cracking process, a reduction in the fire and risk hazard and an absorption plant which captures the gases that fail to condense and extracts the gasoline by a mineral seal oil or similar medium, adding about 3 per cent. to the gasoline recovery based on the oil run through the still. Following are the percentages of gasoline recovered from some of the heavy crudes with the process operating normally:

Oil Treated	Gravity	Pctg. of 56° B. Gasoline Recovered.
Oklahoma gas oil	32	45
Mexican fuel oil	12	50
California fuel oil	14	47
Caddo heavy crude	12–14	48

NOTE. It is said that in common with other cracking processes it is found more profitable to run the fuel oil down in a coking still into a distillate and put the distillate through the cracking still rather than run the fuel oil direct through the cracking stills, some of the carbon being eliminated by the former method.

The description of the process by the inventors and their claims for it, explained by reference to the cuts: Fig. 5, Sec. 4c, shows the apparatus (Fig. 1), and modification (Fig. 2).

" Fig. 1 represents partly in section, and partly in elevation, one form of such apparatus embodying the invention.

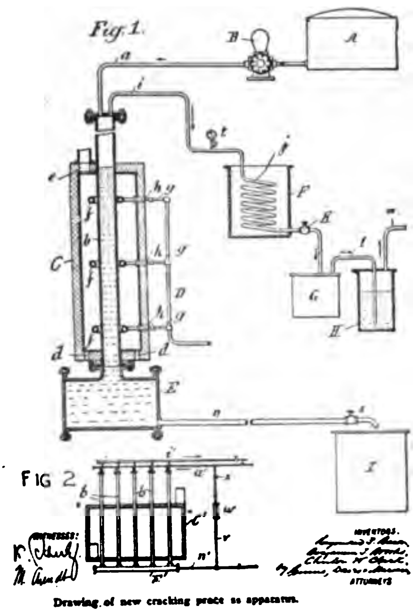

FIG. 5. SEC. 4c.

" Fig. 2 represents a partial view of a modification thereof, applicable to multiple units.

" Similar letters of reference indicate similar parts in both views.

" Referring particularly to Fig. 1, *A* indicates a storage tank for the petroleum hydrocarbons to be treated and *B* indicates a pump for delivering a regulated supply therefrom to the still through the conduit (*a*).

" In Fig. 1 is shown a single unit consisting of a tube (*b*), of steel or other suitable metal, whose length is preferably 20 feet or more, when the internal diameter of the tube is 6 inches. The heating zone of the tube is intermediate of its ends, and, in the form shown in Fig. 1, consists of a fire-brick chamber *C* having suitable air inlets, as (*d*), and a suitable exit opening, as (*e*), for the products of combustion. The chamber *C* may receive its heat from any convenient source, as, for instance, a series of annular gas burners (*f*), supplied with gas from the gas conduit *D*, whose branches (*g*) terminate in injecting tips, as shown, which draw in a suitable supply of air through the bells (*h*), opening into the atmosphere. At its lower end, the tube (*b*) communicates with a tar and coke receiving receptacle *E* located below outside of the heating zone.

" While the production of the desired product depends upon the maintenance of the high temperature and high pressure hereinafter described, the rate of production is a function of the area of heating surface employed, and, for most purposes, may be regarded as represented by the ratio of the heating surface to the volume of the oil within the heating space. Accordingly, it is found that the maximum yields, in a given unit of time from a given volume of oil heated, are obtained when the ratio of the heating surface to the volume is correspondingly large. In prac-

tice, we have employed with entirely satisfactory results, tubes of an internal diameter as large as 19 inches (corresponding to a ratio, expressed in comparable units, of internal periphery to internal capacity of 1:4.7; this numerical ratio being derived when the inch is taken as the unit of measurement). We do not recommend the employment of tubes of materially larger diameter because of the rapidly decreasing yield in gasoline beyond that point.

"At the beginning of the operation, the charge of oil to be cracked and distilled is established up to the level indicated in Fig. 1; that is to say, at a level slightly higher than the internal wall of the top of the heating chamber *C*. This level of the body of oil is kept practically constant, by means of the pump *B*, which supplies oil to the interior of the tube as the cracking and distillation proceed. Accordingly, the products of combustion do not come into direct contact with any portions of the tube not occupied by the liquid oil, and consequently, the danger of destructive decomposition of any portion of the vapors by coming into contact with overheated portions of the tube above the zone of liquid oil is minimized and the formation of an adhering layer of coke upon such portion of the walls of the tube is avoided.

"The free portion of the tube extends above the furnace setting, as shown, for a distance of, say, 5 feet. The vapors pass, by means of the pipe '*i*,' to the condenser coil (*j*), contained within the cooling receptacle *F*. The condenser coil is provided at its end with a valve (*k*) and discharges into the receptacle *G*. The uncondensed gases and vapors from the receptacle *G* pass by the pipe *L* into a body of oil contained within the receptacle *H*, wherein such particles of oil as are contained in the residual gases are trapped and recovered. The surplus gases and vapors pass off through the conduit (*m*). At the bottom of the receptacle *E*, a pipe (*n*) conveys the residual tar and coke to a receiving tank *I*, the flow being under the control of a regulable valve (*s*).

"The mineral oils to be treated in the apparatus and from which the desired product is to be obtained are petroleum hydrocarbons, as, for instance, American and Mexican petroleum. With the form of apparatus shown in Fig. 1, the receptacle *E* and the tube *B* are filled to the level indicated, and the annular burners (*f*) are ignited. The temperature then rises to the range of from 662 F. to 932 F., and the pressure is likewise permitted to rise, by shutting off the valve *K* either wholly or partially, as the case may be, until the pressure gauge (*f*) indicates the pressure."

The other processes are described in standard works on the subject and in Government bulletins.

After the "cracking process" is completed, a "residuum" of a heavy, tarry liquid remains in the still. In the old method of refining, this residue was taken to the "Tar Still," as previously described, but with the advent of the "Tower Still" the refinement is carried on to completion in the same still.

The "residuum" is now distilled by increasing the temperatures, and a heavy distillate is taken off at the first trap, an "intermediate distillate" at the second trap, and a "light distillate" at the third trap, while "tar coke" remains in the still.

The first distillate is "wax bearing," and in the last part of the run is known as "wax tailings." The third distillate is a high-test oil, such as "300° oil," while the second distillate is of an intermediate character.

BLACK OILS.—Black oils are marketed as " Summer " and " Winter " black oils. The " Summer " black oils have a higher viscosity than " Winter " black oils, and the cold test of the winter oil is lower by about 15° to 20° F. than that of the summer oil.

The usual method of making black oils is to thin out petroleum residuum with distilled oils from the intermediate cut.

" Summer " black oils have less of the distilled oil in their makeup than " Winter " black oils have.

There are numerous ways of making black oils, but the above method may be considered as a typical one.

* **THE WAX-BEARING DISTILLATE.**—This distillate is pumped to the " Chilling Machines," in which it is passed through cylinders, inside of which are inner cylinders containing cold brine.

THE CHILLING MACHINE.—The machine consists of a series of cylinders, inside of which are other cylinders, which are of smaller diameter, thus providing an oil space between the two cylinders. The outer cylinders are stationary, and the inner cylinders are revolved by means of gear wheels, as shown. On the outside of the revolving cylinders are scrapers, which are placed there to prevent the oil flow from becoming sluggish, due to the chilling and solidifying of the wax contained in it. The hot oil from the stills is pumped into the same end of the machine that the hot brine leaves, so that as it flows through the machine it is chilled more and more, and as it approaches the point of entry of the cold brine its temperature has reached 20° to 25° F.

THE WAX PRESS.—The cold wax distillate is pumped to the " Wax Press " after leaving the chilling machine. (See Fig. 6, Sec. 4c.)

Fig. 7, Sec. 4c, shows the general outline of a " Wax Press." The cold wax slop is pumped into the press through a pipe. The cylinder and plunger are used to push the plates against each other, so that the iron rings around the outer edges of the plates form a tight, leakproof joint.

The plates or " Bags " are shown in Fig. 8, Sec. 4c. The iron ring *V* has at its centre a sheet of canvas of a special weave. In the centre of the canvas is an opening *U*. Two of these rings are pushed together to form a compartment *B*.

The oil and wax enter through a pipe and flow into the compartments *B*. The pump pressure on the oil forces it through the canvas *K*, as shown. The oil drips down into a trough, where it is collected and piped to the lubricating department. Here it is separated into the various bodied lubricating oils, called " Paraffin Oils," by means of steam stills.

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* Note. The crude lubricating distillate or wax-bearing distillate is put in a steam and fire still to change the character of the paraffin wax content, by heat, to the crystalline condition from the amorphous condition. Then it is given an acid and alkali treatment and thence to the chilling machine.

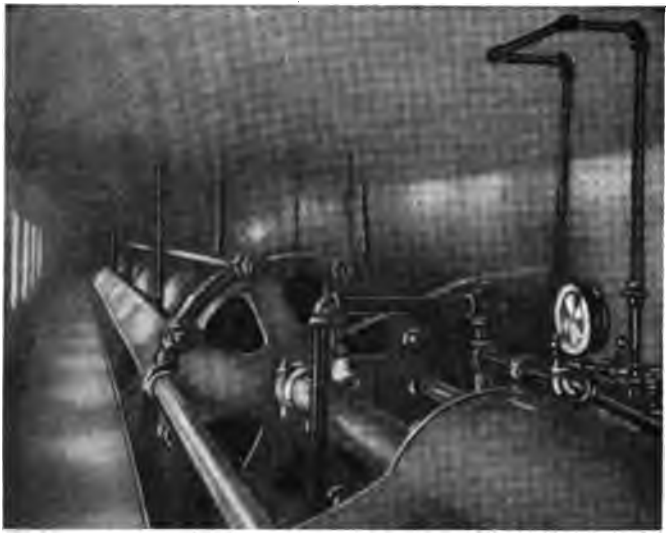

FIG. 6. SEC. 4c.—View showing a wax press.

FIG. 7. SEC. 4c.—Detail view of Carbondale high pressure filter press, illustrating the arrangement of screw conveyor for removing "slack wax" and the oil trough for carrying away the "pressed oil."

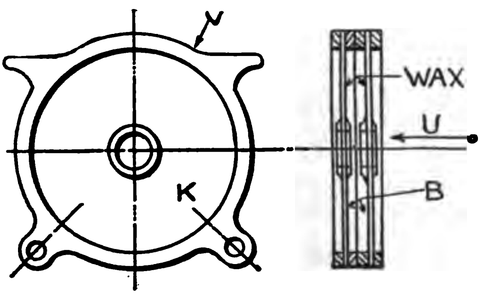

FIG. 8. SEC. 4c.—Outline of press plates or bags.

PARAFFIN WAX

SLACK WAX.—The wax collected on the canvas plates is removed with chipping chisels, or "spuds," as they are called. It falls through into a trough. There is a screw conveyor that carries the wax to the "Slack Wax" tank, where it is melted and pumped to the "Sweating Sheds." Slack wax contains about 50 per cent. paraffin wax and 50 per cent. oil.

SWEATING SHEDS.—Referring to Fig. 9, Sec. 4c, which shows the general appearance of a "Sweater," it can be seen that it is composed of a number of pans which are held on racks in the shed. Each pan is equipped

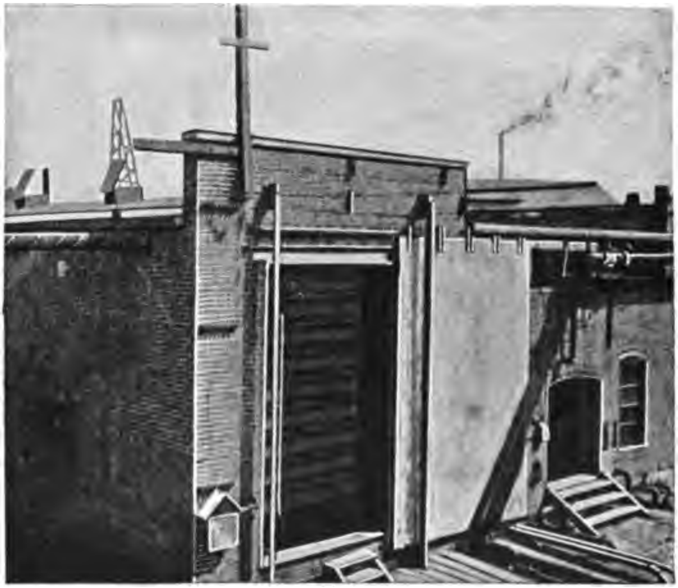

FIG. 9. SEC. 4C.—A sweater shed.

with a coil of pipe run near the bottom. The oil and melted wax are run into the pans and then chilled by water running through the pipes until it is solid. The temperature of the solid mass is next slowly raised, and under these conditions the oil is gradually sweated from the wax and flows away, carrying with it most of the coloring matter contained in the slack wax.

PARAFFIN SCALE WAX.—If the sweating process is stopped when the wax contains a low percentage of oil, the wax is called "Paraffin Scale."

SWEATED WAX.—A wax sweated free from oil is called "Sweated Wax." By resweating, different grades of wax may be obtained, ranging in melting-points from 115° F. to 136° F.

DECOLORIZING.—The yellow sweated wax may be melted and filtered through bone dust or Fuller's earth, and the product is called

"Refined Wax," and should be colorless, odorless and tasteless. When the filtering medium becomes exhausted, the wax becomes more and more colored and is called "Semi-refined Wax."

METHOD OF TREATMENT.—The crude wax is filtered or percolated through clay or bone black to remove the asphaltic coloring matter contained.

The clay used has similar properties to bone black; *i. e.*, it absorbs tarry and asphaltic compounds. This clay is obtained usually in Georgia and Florida. It is mined, roasted, broken up and sifted before using. It is porous and light, and is called "Fuller's earth."

The clay is placed in large upright cylinders, which hold 10 to 20 tons of clay and which have perforated bottoms. The wax is melted and is poured in at the top. The first drippings are colorless, but as the filtration proceeds, the color approaches nearer to that of the crude wax.

As a matter of interest, the proportion of clay used is about one (1) ton of clay to about 5 or 6 tons of wax, first quality.

The clay can be used again after burning out the coloring matter and asphaltic compounds retained by the clay in cement kilns.

FOOT'S OIL.—When slack wax is sweated, it is separated into crude paraffin wax and what is known as "Foot's Oil."

NOTE. See index for commercial grades of wax.

PARAFFIN OIL.—The oil from the presses is treated, redistilled and manipulated to produce the various oils, ranging from the light spindle oils to the heavy machine oils, known as " Paraffin Oils," which are always obtained from oil that has been cracked. The oils may be treated with sulphuric acid to throw down the unstable compounds, free carbon, etc., washed with water, neutralized with an alkali, and the whole again washed and separated. The remaining oil is then blown with air to remove any traces of water that may be present.

Sometimes the oil fraction is partially decolorized by sulphuric acid treatment, and is then filtered to complete the decolorization necessary to produce marketable standards. These oils may be called " Filtered Oils." Oils produced by these processes are brilliant to the eye. When oils are refined by these processes they contain hydrocarbon sodium salts (" Sulpho "). Oils containing these sulphuric or sulphonic compounds will form a curdled mass when mixed with water to a more or less extent, depending upon the amount of " sulpho " compounds present.

" Paraffin oils " make very satisfactory lubricants and have good wearing qualities. They should never be used in the crank-cases of " splash-fed " steam engines, in steam turbines or any machinery in which the lubricant is likely to come into contact with water. The gravities of paraffin oils usually run between 21° and 26° Baumé.

COKE.—About 5 per cent., by weight, of the crude remains in the still as "Coke." It is removed by breaking it into small pieces, running for Mid-Continent crude from 5 inches to 8 inches in thickness, and as high as 30 inches in thickness from Mexican crude.

This "Coke" is sold to manufacturers of electric-light carbons and carbon points and to other industries requiring pure carbon. Petroleum coke contains about 99 per cent. of pure carbon.

Petroleum coke is marketed as "Chipped" and "Unchipped" coke. When the coke is removed from the still it has a brownish crust. This crust contains the sand and other impurities that entered the still with the crude oil. "Unchipped coke" has this crust still on it, and "Chipped coke" has been stripped of the crust.

FRACTIONAL DISTILLATION

This distillation, with bottom steam, is designed to prevent as much as possible the decomposition of the petroleum. This is particularly important when lubricating oils, cylinder stocks, etc., are to be obtained from the oil.

The steam is carried into the still by means of perforated pipes, so arranged that it is directed onto the bottom of the still, distributing and thus agitating the oil. This will prevent the oil from overheating, due to overlong contact with the still bottom. Another feature is the fact that, due to the atmospheric pressure on the mixture of steam and hydrocarbons being divided, the partial pressure on the oil is less than the atmos-

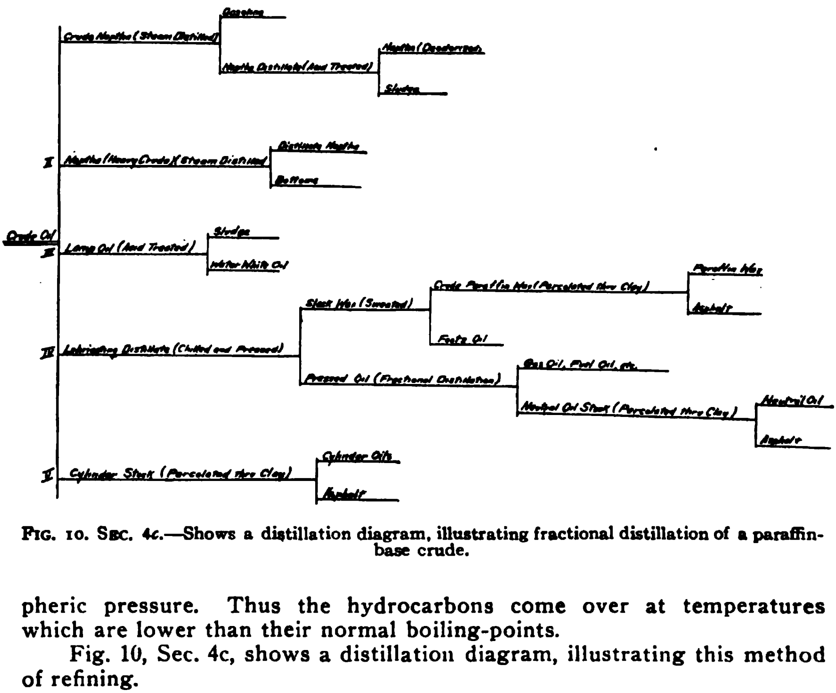

FIG. 10. SEC. 4c.—Shows a distillation diagram, illustrating fractional distillation of a paraffin-base crude.

pheric pressure. Thus the hydrocarbons come over at temperatures which are lower than their normal boiling-points.

Fig. 10, Sec. 4c, shows a distillation diagram, illustrating this method of refining.

In the case of fractional distillation with steam, for a paraffin base crude as an illustration, when the distillation of the natural lamp oil has been completed, the distillate in the still is only about 500° F., while in the case of distillation without steam the temperature is about 630° F. at this point.

At this point, instead of trying to increase the cracking by slowing the rate of distillation, as in the case of distillation of a mixed base crude, the amount of steam in the still is increased and the distillation carried on as fast as possible to avoid cracking. This is continued until the lubri-

cating distillate, which will average about 28 per cent. of the crude, has been distilled over, then at this point the temperature in the still has reached about 620° F., and at this point the distillation is stopped, which leaves in the still the cylinder oil stock. In the cracking process the temperature at this similar point reaches about 850° F., and instead of cylinder stock the residue in the still was solid coke. In the fractional distillation as above described the whole distillation is conducted with the aim to produce as large a yield of cylinder oil as possible. As can be seen from reference to the diagrams, the method and products of refining are about the same up to the point where cracking would have occurred, as described in the Cracking Process. The cylinder stock remaining in the still is then ready for sale as unfiltered cylinder oil, or it may be percolated through clay to give the filtered oils.

The crude cylinder stock may be thinned down with blending naphtha and put in a chilling tank, where the amorphous wax (crude petrolatum) is settled out. This has the effect of lowering the cold test of the cylinder oil. The blended stock is then filtered to better the color and the naphtha then taken off in a steam still. The moisture is driven off by air blowing.

If a mixed base crude has been fractionally distilled, as described for a paraffin base crude, the crude naphtha would be distilled off, then the crude heavy naphtha, then the natural lamp oil, then a distillate containing wax and lubricating oil, leaving in the still a residue of soft pitch. This residue would run about 15 per cent. of the crude. The still temperature would have only reached about 630° F. This residue has the property of being vulcanized by the action of air at about 500° F. or by sulphur at about 400° to 450° F. This process, when carried out in a still consists in heating the residue to the desired temperature and pumping air through the contents for about two days, the length of time depending upon the hardness desired, and the resulting hard pitch produces the so-called "road binder" of commerce.

VACUUM PROCESS.—Some refiners use a pump to create a partial vacuum in the still in conjunction with steam distillation. It is claimed that in this manner the oil is distilled over at very much lower temperatures than their normal atmospheric boiling-points. It is believed by some authorities that the quantity and quality of the distilled products are better with the vacuum process. However, other authorities, particularly in America, do not consider the additional cost of the method and the necessary equipment to be worth using when they consider the very slightly improved results obtainable.

FRACTIONAL REFINING NOTES.—The fraction remaining in the still after the burning distillate has been taken off is commonly called "Wax Slop."

A heavy burning distillate may be obtained from the "slop" and some so-called "gas oil," also 300° or Mineral Seal Oil.

The lubricating distillate is then chilled and pressed for the wax. This distillate is put through the same processes for the removal of the wax and gas oil as the "paraffin oils" were, the only difference being that the resulting lubricating stocks or pressed oils are not usually treated with sulphuric acid, but are brought to the desired color by percolation through Fuller's earth to produce the "neutral" spindle oils of commerce.

NEUTRAL OILS.—The term "neutral oils" is given by the trade to those lubricating oils obtained by distillation without cracking. There are "treated neutrals" and "filtered neutrals." Usually neutral oils are filtered, however, to preserve their qualities. "Treated neutrals" will run a little lower in gravity than "filtered neutrals." The gravities of "neutral oils" are higher than those of "paraffin oils."

"Neutral oils" are sometimes referred to by the trade as "Viscous" and "Non-viscous Neutrals." Generally speaking, neutral oils above 135 Vis. @ 100° F. are called Viscous Neutrals, and those below 135 Vis. @ 100° F. are called "Non-viscous Neutrals."

Neutral oils are sometimes "debloomed" to remove the "cast" or "bloom." "Deblooming" is the process of exposing the oil in shallow tanks to the weather. This process bleaches the oils and makes them hold their color. The "cast" or "bloom" of an oil can be easily detected by placing a drop on a black surface and viewing it by reflected light. The cast will be detected by a bluish color. Neutral oils are sometimes used to adulterate cotton-seed oil and other outside oils, and a cast or bloom would reveal their presence to an experienced observer.

The most important difference between the characteristics of "neutral" and "paraffin" oils is their behavior in the presence of moisture.

Filtered neutral oils will not emulsify when in contact with water, as will paraffin oils, and, while there are some "paraffin oils" on the market which have very good non-emulsifying qualities, it is always dangerous to use them in any place where they are liable to be exposed to water. Neutral oils should be used for crank-case lubrication of steam engines, in circulating systems, for turbine lubricating systems, etc.

SECTION 4d

DATA ON PETROLEUM PRODUCTS

DATA ON PARAFFIN WAX

* **TYPICAL GRADES.**—Paraffin wax is usually marketed according to the following named commercial and refinery grades—the temperatures given refer to American Melting Points:

CRUDE AND SPECIAL WAXES

A. M. P.	
105° F.*	—Match wax.
108°/112° F.	—Match wax.
111°/113° F.	—White crude scale wax.
117°/119° F.	—Yellow crude wax.
122° F.	—Semi-refined wax.
124°/126° F.	—Special white wax.

REFINED WAXES

115° F.	—Fully refined paraffin wax.
118°/120° F.	—Fully refined paraffin wax.
122° F.	—Fully refined paraffin wax.
122°/124° F.	—Fully refined paraffin wax.
125°/127° F.	—Fully refined paraffin wax.
128°/130° F.	—Fully refined paraffin wax.
130°/132° F.	—Fully refined paraffin wax.

PACKINGS FOR PARAFFIN WAX.—Tight oil barrels: For match wax (105°); match wax (108°/112°); burning wax (for miners' lamps).

Slabs, in bags: For refined waxes.

Slack barrels: For crude scale wax and refined wax.

Cases: For refined wax and burning wax for miners' lamps.

MELTING POINTS FOR PARAFFIN WAX.—The American melting points for paraffin wax range 3° F. higher than the English melting points, *e.g.*, 122°/124°, English melting point, is equivalent to 125°/127°, American melting point wax.

The "English Test," which is in reality the solidifying point, is determined by stirring the melted wax in a small cup about 2½ inches in diameter by about 2 inches deep until the latent heat given up by the crystallization of the wax arrests the fall of the mercury column momentarily. This temperature is the test temperature.

"The American Test" gives results that are about 2½° to 3° F. higher than the "English Test," and it is determined as follows: A hemispherical cup 3¼ inches in diameter is three-quarters filled with melted wax, which is allowed to cool without stirring until a thin film forms on the top of

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* See index for Paraffin Wax for other references.

the liquid wax and extends from the sides to a thermometer with a round bulb one-half inch in diameter, suspended so that it is three-quarters immersed in the centre of the cup. As the "American Method" is slow, it is often customary to take the "English Test" and add 3° F. to the result for the "American Test."

* **CHEMISTRY OF PARAFFIN WAX.**—Paraffin wax consists of a mixture of hydrocarbons of the paraffin series, about $C_{22}H_{46}$ to $C_{35}H_{72}$. The commercial article is rated according to the melting point and as to whether it is refined or crude.

Paraffin exists in crude petroleum in the form of protoparaffin. In the protoparaffin condition it does not crystallize out, nor can it be pressed from the oil at low temperatures. To obtain the crystalline pyroparaffin the oil is subjected to destructive distillation, which produces the crystalline pyroparaffin and puts it in a condition for refrigeration and filtration.

† **USES OF PARAFFIN WAX.**—"Crude Wax": This product is sold to match factories as "Match Wax," for use on the heads of matches. It is also used in leather tanneries as a stuffing or loading for the leather. It is also sometimes used for burning in special lamps used by miners and for marine bunker lights. It is useful also for waxing yarn in the textile industry to act as a softener and lubricant for the yarn during winding. The customary melting ranges for the two regular grades of wax are 117°–119° F. and 124°–126° F. Crude wax may be used for any purpose where a petroleum taste and odor are not objectionable. It is shipped either in slabs or solid in barrels. The slabs are packed in cases of about 250 pounds, or in jute bags of about 225 pounds.

"Refined Wax": This product should be free from taste and odor. It is used for such purposes as a coating for cheese, electrical insulation, coating for beer vats, artificial flower manufacture, coating vinegar and cider barrels, lining butter tubs, coating butter cartons, coating paper milk-bottle tops, coating paper drinking cups and milk bottles, sealing preserves and jams, coating the necks of drug bottles, etching, also for coating meats, sausages and any product which must be prevented from drying out and losing weight. Some other uses are: Coatings for whiskey, alcohol, molasses and sourkraut barrels, polishing wooden handles, spokes and wooden ware, saturating paper used in waterproof signs, oyster and ice-cream pails.

It is shipped in 20-pound slabs usually, and packed either in jute bags or wooden cases. A brief description of the method of using wax to coat cheese is as follows: The wax is used to improve the appearance of the cheese and to prevent the accumulation of the green mould, which will

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* Note. The solid hydrocarbons called paraffin wax according to several authorities belong chiefly to the paraffin series, C_nH_{2n+2}.

† Paraffin is soluble in mineral oils, ether, benzine, and essential oils. It is partially soluble in hot alcohol (absolute), but separates on cooling. It is insoluble in rectified spirit. Boiling in concentrated nitric acid oxidizes it. Heating with potassium permanganate also oxidizes paraffin. Chlorine slowly attacks melted paraffin. Paraffin is decomposed when heated with sulphur, surphuretted hydrogen being formed and carbon deposited.

appear on cheese that is not frequently handled. It also prevents shrinkage and evaporation of the cheese. The wax is melted in a large vat, which is heated by steam pipes or hot-water baths. A direct flame cannot be used, because of the danger of charring the wax. The cheese is immersed in the melted wax for a few seconds, and it is then placed on a rack for cooling. Usually the cheese is waxed when it is received at the storage warehouse and when it is from one to two weeks old. This coating for cheese boxes and butter tubs permits them to be shipped dry, improving their appearance and preventing burst hoops from water-soaked staves.

PETROLATUM

GENERAL DATA.—This product when highly refined is also sometimes called vaseline, and is sold by a concern specializing on this product. Petrolatum consists of the higher members of the Paraffin Series, which settle from certain kinds of petroleum mixed and inseparable from some of the oily constituents of the oil. Its uses for the light-colored or filtered material are medicinal and for the toilet, or as dark-colored material it is used by makers of oiled paper and for the purposes as outlined elsewhere. (See index.)

Bacon and Hamor, "American Petroleum Industry," classify the commercial varieties of petrolatum under two heads:

1. Those which, like vaseline, are obtained, as a ready-formed mixture of hydrocarbons of gelatinous consistence.

2. Those made by directly mixing solid paraffin of low melting-point with heavy lubricating oil, such as are known in Germany as "artificial vaselines." The latter varieties are less homogeneous and are liable to deposit granules of paraffin on keeping, and they are, therefore, not suited for the preparation of ointments, as is the true American petrolatum.

The viscosity of Natural American Vaseline is given as:

	45° C.	50° C.	80° C.	100° C.
Engler Vis.	4.8	3.7	2.1	1.6

Petrolatum is also called petroleum jelly, petrolatum ointment, petrolatum album, and white petroleum jelly, according to its degree of refinement, by the medical profession.

It is insoluble in water and easily soluble in ether, chloroform, oil of turpentine, benzine, carbon bisulphide, petroleum benzine, and also most of the fixed or volatile oils.

The specific gravity ranges from about .820 to .865 at 60° Fahr.

It does not oxidize on exposure to the air, and is not readily acted upon by chemical reagents.

WAX TAILINGS

GENERAL DESCRIPTION.—This name is carried over from the time when the old-style Tar Stills were used.

After the "*natural oils*" were taken off and the oil was cracked for "*export white oil*," the residue in the still was cooled and put in a tar still. Here it was run to dryness. After the wax-bearing distillate was all taken off and just before the residue in the still became dry and coked, a heavy distillate came over. This distillate was called "Wax Tailings." It contained no wax, which makes its name misleading. It is very adhesive, and at atmospheric temperature it looks like bees'-wax. It is so adhesive that it would clog up the condenser if allowed to get in there. In fact, it must be aided with steam in its flow through the outlet pipe.

Originally it was taken out of the still to permit the residue to coke and dry, as otherwise the mass would be sticky. It was formerly burned under the stills, until a use was found for it in making prepared roofing, etc.

SHIPPING OF WAX TAILINGS.—Directions for loading: Tailings should be loaded at a temperature not to exceed 140° F. The cars should be filled into the dome sufficiently to compensate for shrinkage between the loading temperature and 80° F. and leave the car flush at the lower temperature. Calculating for shrinkage should be made by using a coefficient of expansion of 1 per cent. for every 32° F., or .03125 per cent degree F. Invoices should be made on the basis of the car and dome measurements, corrected for the expansion to 80° F., as indicated above, and in no case to exceed the shell capacity of the car. The weight equivalent of one gallon of tailings at 80° F. is taken as 9.18 pounds.

PETROLEUM PITCH

GENERAL DESCRIPTION.—This is a black oil product. It is sometimes used for electrical purposes, for insulation as a coating for underground cables. It is also used by prepared roofing manufacturers as a coating for roofing felt, which has previously been saturated or filled with products similar to Petroleum Tailings.

Sometimes Gilsonite is mixed with the pitch to improve the coating of the finished roofing. This product is usually sold in metal drums, averaging about five drums to the ton.

OIL ASPHALTS

GENERAL DESCRIPTION AND USES.—According to the amount of distillate removed from the crude oil, oil asphalt is thickly fluid or a solid substance.

The solid grades run from a consistency which may be worked with the fingers to a consistency that is very hard. Oil asphalts are little affected by water, either pure or mineralized, or by solutions having an alkaline nature. It is claimed that their immunity from decay in contact with water fits them for street paving, where natural asphalts are decomposed. In contact with air they are reasonably durable, though somewhat less so than natural asphalts. The mineral matter contained in oil asphalts is very low, usually only a trace being present. Their freedom from insoluble matter is said to render them very suitable for the preparation of paints and varnishes. They are widely used for dipping, coating, saturating, etc., and can be made very fluid when melted, which they do at comparatively low temperatures. They have good adherence to paper, wood and metals, and form a close, brilliant coating.

One of the main uses for the liquid asphalts is as fluxes for the natural asphalts.

TYPICAL TESTS OF OIL ASPHALTS

	Mexican	Mid-Continent air blown	California
Bitumen	99.5%	99.2%	99.5%
Mineral matter	0.3%	0.7%	0.3
Fixed carbon	17.5%	12.0%	15.0
Specific gravity	1.040	0.990	1.045
Melting point (Fahr.)	140	180	140
Penetration	55	40	60
Petroleum ether soluble	70.0%	72.0%	67.0%
Sulphur (ash free basis)	4.5%	0.60%	1.65%
Free carbon	0	0	0
Cementing properties	Good	Poor	Good

TYPICAL TESTS OF NATURAL ASPHALTS

	Natural Trinidad	Cuban	Bermudez
Bitumen	56.0%	75.1%	94.0%
Mineral matter	36.8%	21.4%	2.0%
Specific gravity	1.40	1.305	1.085
Melting point (Fahr.)	190	Cokes 240	180
Penetration	0.5	0.0	2 5
Petroleum ether soluble	65.0%	41.4%	70.0%
Sulphur (ash free basis)	6.0%	8.3%	5.6%
Free carbon	6.0%	3.5%	4.0%
Fixed carbon	11.0%	25.0%	13.5%
Total carbon (ash free)	82.6%	......	82.5%
Hydrogen (ash free)	10.5%	......	10.3%
Nitrogen (ash free)	0.5%	......	0.7%

SHIPPING WEIGHTS.—One net ton of 2000 pounds.

Packing:	Drums, each drum weighs	12 pounds tare.
		400 pounds net.
		412 pounds.

Hence there are 5 drums to the net ton of 2000 pounds, naming a gross weight of 2060 pounds per ton of asphalt shipped.

Measurement of drums: Diameter, 22 inches; height, 39 inches. Cubic measurement, 8.58 cubic feet.

One ton of 5 drums measures 42.90 cubic feet.

Weight per gallon of asphalt, 8 1/3 pounds net.

Two hundred and forty gallons of asphalt per ton of 2000 pounds.

GENERAL NOTES.—Water is a common impurity in oils used for making asphalt. This water is removed by settling, or, in cases where the oil has nearly the same gravity as water, dehydration processes are used.

In distilling an oil for road purposes, an effort is made to cause distillation at a sufficiently low temperature to prevent decomposition of the hydrocarbons, and, therefore, after carrying the distillation part way with fire, it is usual to continue with superheated steam.

Blowing air through the oil at a medium high temperature is another method used, and with certain Mid-Continent crudes the asphalt yield is said to be increased, and the product is less affected by temperature changes than are natural asphalts. This type of asphalt is generally used for roofing and brick- or wood-block filler; also as an asphalt flux.

PROPERTIES AND CHARACTERISTICS

ACTION OF HYDROCARBON OILS UPON METALS.—Redwood states (*Lubricants, Oils and Greases*, p. 44): "Dr. Stevenson Macadam has investigated the action of paraffin-burning oils upon metals, and states that the action varied with different samples of such oils, and that the variation was not traceable to the presence of impurities." * * * "In this connection it may be remarked that the action of hydrocarbon oils on metals has been generally considered to be due to impurities, such as water and slight traces of phenol and bases, which most commercial petroleum oils contain."

EVAPORATION OF OIL.—(C. P. Bowie, Bulletin 155, Petroleum Technology 41, Bureau of Mines, U. S. Department of the Interior, 1918, p. 51). Mr. Bowie, in connection with his work on oil storage and reservoirs, says: "The accepted theory regarding the constitution of matter and the nature of heat assumes that all liquids are composed of molecules, which are held together by mutual attraction. When the liquid is warmed above minus 273° C. the molecules are in constant and rapid motion, and, as a result, there are spaces between them. As heat is applied to the liquid the molecules move more and more rapidly and strike against each other with greater force, separating further against the force of cohesion. Molecules near the surface of the liquid, and vibrating rapidly, pass out from it. Some are drawn back again into the liquid by cohesion, but some escape into the air above the liquid surface. If the vessel containing the liquid is open, in time all may escape. However, if the vessel is tightly closed, the molecules cannot escape from it, and even though it be only partly filled with liquid, the air above the surface soon becomes so filled with vibrating molecules that the number leaving the surface of the liquid in a given time is just equal to the number going back into it. The air above the liquid is then saturated and evaporation ceases. If the temperature of the liquid in the closed vessel is increased, vaporization again takes place, but ceases as soon as the air in the vessel above the liquid becomes saturated for that temperature. However, the pressure in the vessel is increased. If the warm saturated air is cooled some of the vapor condenses and returns to the liquid and the pressure is decreased."

SECTION 4e

GASOLINE AND ENGINE FUELS

TYPES OF GASOLINE ENGINE FUELS.—There are three main types of gasoline on the market at present (1918):

1. Straight refinery gasoline.
2. Blended, casing-head gasoline.
3. Cracked and blended gasoline.

"Straight Refinery Gasolines" are produced in various ways according to the section of the country. They are generally characterized by a low content of unsaturated and aromatic hydrocarbons, and by a distillation range that is free from marked irregularities. The crude oil is distilled in fire stills and cuts made according to a predetermined gravity. The crude naphtha thus obtained is then acid-refined and steam-distilled, and several products of different ranges of volatility may be produced.

"Blended Casing-head Gasoline": This is obtained from natural gas by compression or absorption. As it is too volatile for general use, it is blended before marketing with heavy naphtha to produce a cheap, safe fuel. This gasoline is distinguishable by having a distillation test showing considerable percentages of low and high boiling-point products, but an absence of the intermediate products.

"Cracked and Blended Gasolines": The cracked, or synthetic, gasolines are important factors in the present market. According to E. W. Dean, of the Bureau of Mines, Department of the Interior, in a paper on "Motor Gasoline," the cracked gasolines are similar to "straight refinery gasoline in most chemical and physical properties, but differ chemically in containing varying percentages of unsaturated and aromatic hydrocarbons." Mr. Dean states that it has been demonstrated that these constituents, if present in moderate proportions, do not decrease the value of the gasoline, and that competent authorities concede that by proper engine equipment and adjustment it is possible to use unsaturated hydrocarbons in practically unlimited proportions.

GASOLINE.—General: Gasoline is composed usually of from 83 to 86 per cent. of carbon and the remainder hydrogen. When spread in thin layers it should be completely volatile within a reasonable time. When agitated with air it should be vaporized readily to form an explosive mixture.

When ignited on the surface in an open container or when spilled on the ground it will burn fiercely, but without explosion. It is explosive only when mixed with air in definite proportions, ranging from 1.5 per cent. to 6 per cent., and when this mixture is brought into contact with a flame of high temperature or a hot electric spark.

Gasolines are mixtures of hydrocarbon compounds, which may be of several distinct groups. They may be saturated compounds or compounds containing the maximum percentage of hydrogen, such as paraffin compounds; or they may be unsaturated compounds, such as ethylene and acetylene hydrocarbons; or ring compounds, of which benzol is the parent member; or the cyclic hydrocarbons which are common to the Russian oils.

The free-burning qualities of gasoline are dependent to a degree upon the proportion of hydrogen which they contain and also to the calorific value.

Compounds belonging to the same family or group have, generally speaking, the same chemical characteristics, but those of different groups are chemically different. For instance, paraffin or saturated, straight-chain hydrocarbons are not easily oxidized or affected by acids or other ordinary chemical reagents. Unsaturated or ring compounds are readily attacked by reagents, especially sulphuric acid. From a physical standpoint, such as gravity, viscosity, fluidity, flash, etc., all compounds, even those from the same family, are different.

CALORIFIC VALUE, POWER, GRAVITY, PERCENTAGE OF SULPHUR OF VARIOUS GASOLINES.—The table following is given in Technical Paper 163, Petroleum Technology 38, on "The Physical and Chemical Properties of Gasolines Sold Throughout the United States during the Calendar Year of 1915," by W. F. Rittman, W. A. Jacobs and E. W. Dean, of the Bureau of Mines. The sources of gasoline are given.

Sample No.	Field from which sample was obtained	Process of manufacture	Gravity		Calorific value of gasoline		Power developed, horse-power-hours per pound of gasoline	Sulphur content, per cent.
			Specific gravity	°B.	Calories per gram.	B. t. u. per pound		
22	Mid-Continent	Cracking plant....	0.745	57.9	11,165	20,097	1.345	0.02
26	Mid-Continent	"Straight" refinery	.742	58.7	11,174	20,113	1.403	.01
43	Mid-Continent	"Straight" refinery	.733	61.0	11,180	20,124	1.350	.05
13	Eastern........	"Straight" refinery	.718	65.0	11,187	20,137	1.405	.04
19	Mid-Continent	"Straight" refinery	.724	63.4	11,215	20,187	1.395	.05
38	Mid-Continent	"Straight" refinery	.727	62.6	11,221	20,198	1.396	.03
15	Eastern........	Blended casing-head	.733	61.0	11,230	20,214	1.376	.03
1	Eastern.......	"Straight" refinery	.724	63.4	11,236	20,225	1.420	.03
34	Mid-Continent	"Straight" refinery	.715	65.8	11,250	20,250	1.365	.02
9	Eastern.......	"Straight" refinery	.687	73.8	11,315	20,367	1.487	.02

GASOLINES; VOLATILITY OF STRAIGHT REFINERY.—The curves given in Fig. 1, Sec. 4e, are taken from the same paper of the Bureau of Mines, as described in the preceding section. They show the volatility ranges of a typical, straight refinery gasoline from Eastern, Mid-Continent and California fields. The authors of the paper call attention to the similarity between the products from the Eastern and Mid-

Continent fields as regards variation, also that California gasolines have a volatility range approximately midway between Eastern and Mid-Continent gasolines.

GASOLINES; VOLATILITY OF EASTERN STRAIGHT AND CASING-HEAD GASOLINES.—Fig. 2, Sec. 4e, shows a set of curves given in Bureau of Mines Technical Paper 163, by W. F. Rittman, W. A.

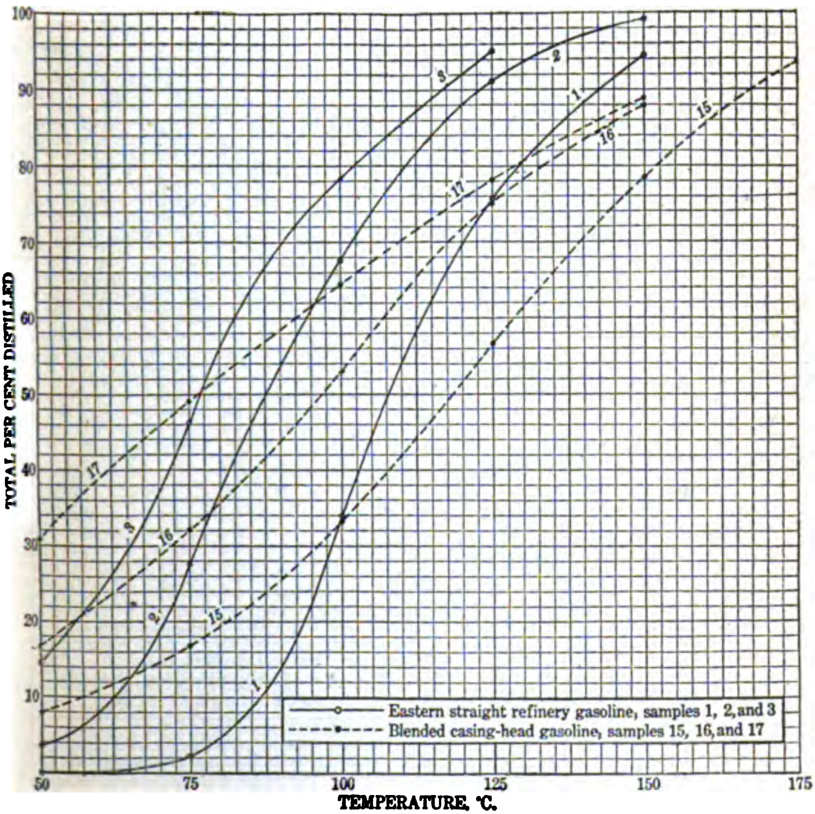

FIG. 1. SEC. 4e.—Comparative volatility of eastern straight and casing-head gasoline.

Jacobs and E. W. Dean, showing the percentages of gasolines of the source indicated, which are distilled off at various temperatures and illustrate the clear-cut difference between the two types of gasolines. The blended gasolines have larger percentages distilled off below 50° C., but have longer distillation ranges.

COMPARATIVE DISTILLATION CURVES, VARIOUS GASOLINES AND OTHER FUELS.—Fig. 3, Sec. 4e, shows distillation curves, compiled by P. J. Dasey, of the Automotive Fuel Society of Detroit.

SPECIFICATIONS.—In specifying gasoline distillation, take the temperature at which 20 per cent. distils off and the temperature at which 90 per cent. distils off, as follows:

20 per cent off at 75° F.
90 per cent. off at 130° F.

This would be called a 75–130 naphtha.

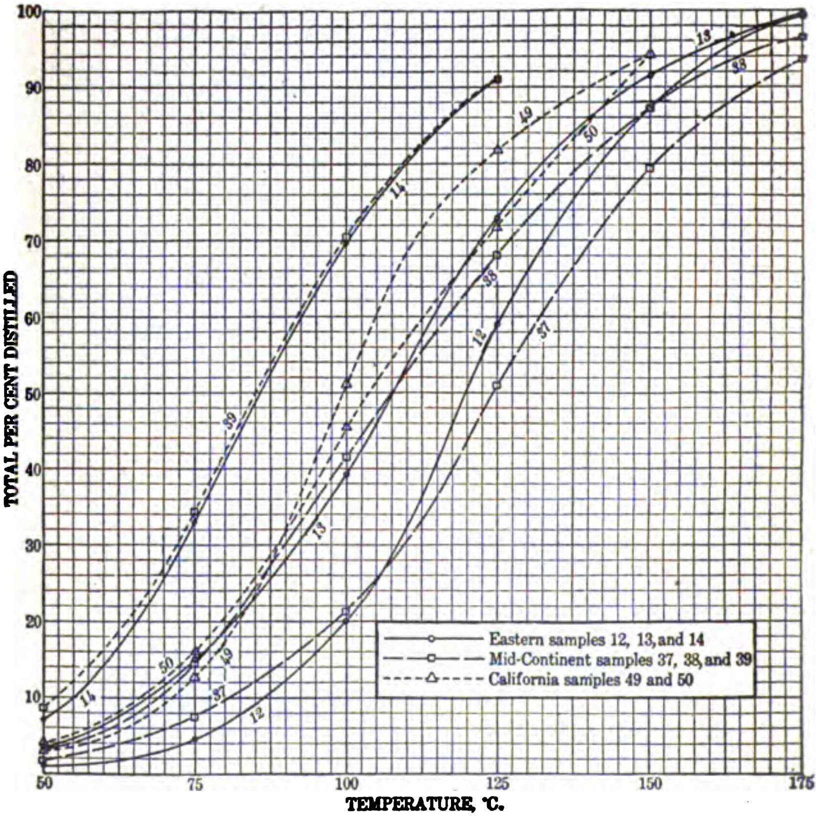

FIG. 2. SEC. 4e.—Volatility of straight refinery gasoline from various sources.

CRACKED GAS CONTENT.—A method used by some to indicate the amount of cracked gasoline in a blended gas is the sulphuric acid test. About 25 per cent. of the cracked gas content of a blend will be absorbed by the acid. Thus if the absorbed volume as indicated by the test is 3 per cent. then probably about 12 per cent. cracked gas is in the blend.

GASOLINE BOILING POINTS.—Gasoline, being composed of many compounds, and since the various compounds have different boil-

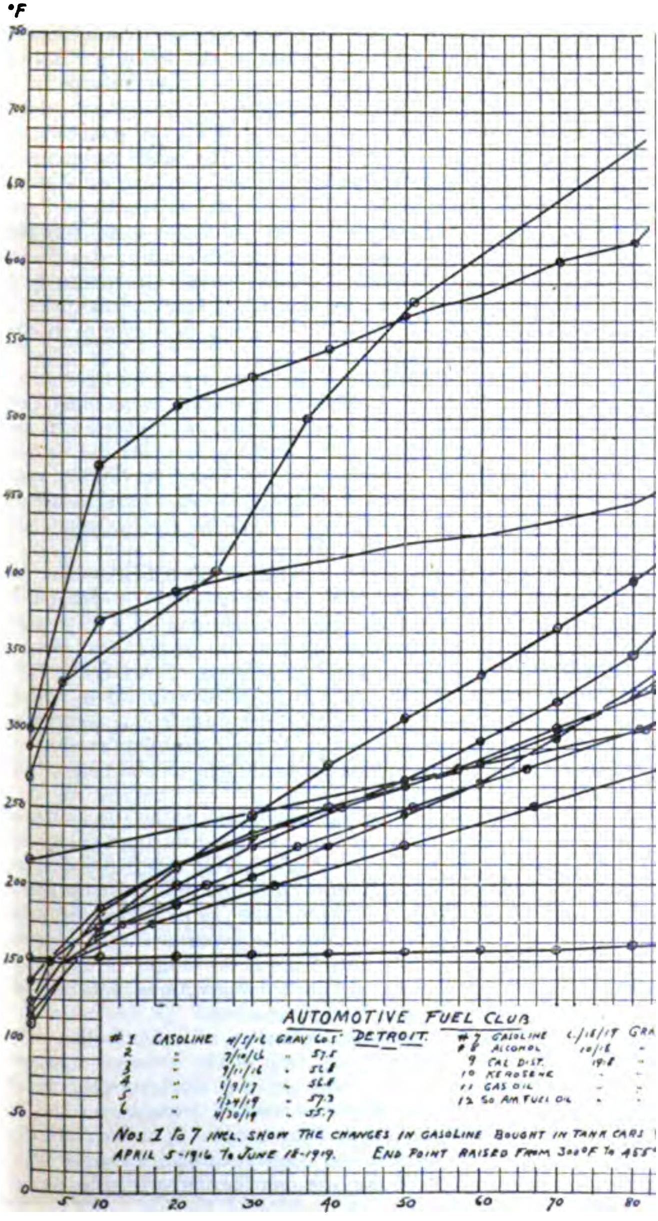

FIG. 3. SEC. 4e.—Distillation curves compiled by P. J. Dasey, Automotive Detroit. (Courtesy National Petroleum News.)

ing points, the mixture will have no fixed boiling point, as is found in substances such as water, for instance. A gasoline will have a "boiling range," which starts at about the boiling point of the most volatile of its constituents, and ranges to about the boiling point of its least volatile constituents. In solutions of different compounds, such as in gasoline, the boiling point of any compound is affected by all of the other compounds.

GASOLINE AND COMBUSTION.—A gasoline for use as a motor fuel should mix quickly and freely with air in the carburetor and be transferred into a vaporized state, so that the mixture will not allow the fuel particles of gasoline to be deposited in any considerable amount as liquid in the manifold or cylinders of the engine. Gasoline has the property of forming explosive mixtures readily with air, even in as small quantities as 1½ per cent. Thus gasoline affords an easy starting motor fuel in cold weather, when liquid fuels vaporize with difficulty.

The short time allowed in a high-speed motor for the fuel to burn—about 1/200 part of a second—demands that the gasoline used must burn quickly and completely. Slow combustion results in lost power and knocking. If the motor fuel's combustion involves complicated or secondary reactions, the high pressures produced by these secondary reactions produce knocking, with a consequent depreciation of the bearings. Poor combustion also produces an offensive odor in the exhaust, and fouling of the spark plugs, exhaust valves and muffler.

GASOLINE SITUATION IN THE UNITED STATES.—The following data were taken from the address delivered by Dr. Joseph E. Pogue, Assistant Director in Technical Matters, Bureau of Oil Conservation, Oil Division, Fuel Administration, before the Motor Fuel Session of the Society of Automotive Engineers, at New York, February 6, 1919:

"The proportion of the crude supply subjected to refining in respect to gasoline has been steadily increasing until the quantity so employed now approximates 95 per cent. of the total. A much smaller proportion, of course, is subjected to complete refining with the production of the whole range of petroleum products.

"Thus practically the whole output has now come to be requisitioned for gasoline production. This is to say that the readiest means for increasing the supply of gasoline (*i. e.*, refining a progressively larger percentage of the crude produced) has been virtually forced to the limit; the 'gasoline slack' within the crude production has been taken up. Thus the most potent circumstance that has thus far enabled the demand for gasoline to increase without a concomitant increase in price is no longer in existence. Further expansion in gasoline output will lie through more difficult avenues than that of merely increasing refinery capacity.

"While dependent primarily upon the quantity of crude refined, the output of gasoline is at the same time a function of the average composition of the various crudes that go to make up the total supply. Since crude petroleum varies in its natural-gasoline content from about 2½ per cent. in the case of heavy asphaltic oils to 25 per cent. or more for light, paraffin oils, it is evident that the gasoline supply will be strongly influenced according to the dominance of the one or other type of oil. As the high gasoline crudes were the first to be exploited in this country, the unmined supply of petroleum has been selectively reduced in gasoline

capacity. The gasoline content of crude oil has been known to decrease even during the life of a given pool, which is a tendency in the same direction as that occasioned by selective extraction in respect to separate pools and fields. So the crude production of the future will show a lower natural-gasoline factor than the crude supply of the past. While this matter cannot be expressed quantitatively, in very rough terms it may be noted that the high-gasoline crudes are about half exhausted, while the low-gasoline crudes, originally of about equal magnitude, are only about a third used up. In other words, the country's gasoline capacity

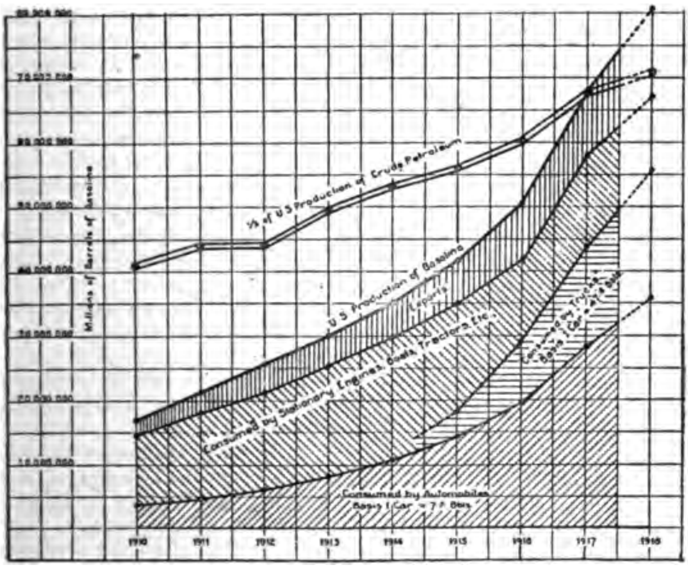

FIG. 4. SEC. 4e.—The gasoline situation. This composite chart is drawn from data as follows: Crude production from U. S. Geological Survey; gasoline production from U. S. Fuel Administration and U. S. Bureau of Mines; automobile and truck consumption based on registration compiled by National Automobile Chamber of Commerce, and consumption factors worked by War Industries Board. This chart is not exact in final detail, but is an interpretation of data approximately correct.

is being drawn upon more rapidly, and hence exhausted more quickly, than is indicated by the condition of the crude supply viewed alone. This tendency was of no immediate consequence so long as it could be compensated by merely refining a greater proportion of the output of crude; but now since practically all of the domestic crude is used for gasoline extraction, a decline in gasoline content can only be offset by shoving crude production to a still higher figure than would otherwise be necessary, or else through a still greater use of means for wresting an unnatural percentage of gasoline from the crude obtainable.

"The means for producing more gasoline than may be obtained by subjecting the total supply of crude to straight refining are: (1) Increas-

ing refinery efficiency; (2) blending high volatile natural-gas gasoline with low-volatile refinery gasoline; (3) increasing the use of cracking in refinery practice; and (4) lowering the volatility of gasoline. All four means are in growing use. For the sake of brevity, the first two may be passed over with the comment that, while important, they have quantitative limitations which prevent them from broadly affecting the situation. This is not true of the second two, whose limitations are of a different order.

"Cracking is a process attachable to straight refining, by means of which low-priced distillates such as kerosene and fuel oil are re-run more vigorously and partly converted into gasoline. Obviously cracked gasoline costs more to produce than natural gasoline, because of a greater consumption of capital, labor, material and fuel, and is commercially possible only after gasoline requirements have approached the quantity producible by straight refining, and so long as there is a certain difference in market value between the raw materials used and the product turned out. The first condition has recently been attained, and there is growing economic room for cracking; the second condition, if the prices of kerosene and fuel oil rise, can be maintained only by a proportionate increase in the price of gasoline."

GASOLINE SUBSTITUTES.—Kerosene, as an automobile motor fuel, requires preheating devices and is difficult to carburett, and certain intermediate reactions in combustion involve knocking and other very objectionable features.

Kerosene requires a hotter spark, higher compression, and runs to better advantage in an engine at a temperature hotter than necessary for a lighter fuel, such as gasoline.

Alcohol is not a serious factor at present, both due to the scarcity of the supply, since the present production in the United States would have to be increased over twenty-five times to approach the gasoline output, and to the fact that alcohol requires compression pressure considerably in excess of the compression in the present-day ordinary automobile engine.

Benzol and benzol mixtures are in some use. The supply of benzol is limited, the available amount being only about 5 per cent. of the yearly gasoline consumption. It has been estimated that if all the coal produced in the United States per year were coked, the total production of benzol would not supply one-half of the motor fuel needs.

Engines using pure benzol must be operated at a maximum power to get economical and carbon-free results.

ALCOHOL.—The development of the manufacture of industrial alcohol has been stimulated by the demands of war. Equipment has been freed by prohibition, which may be in part used for this purpose. There have been handicaps, due to governmental restrictions, etc. However, the cheapness of the necessary raw material may be able to offset these.

Alcohol can be used to advantage only in engines especially adapted to this fuel. Various mixtures of alcohol, benzol, gasoline, and other petroleum distillates have given promising results, however.

Alcohol, benzol, and the lighter petroleum distillates can be rendered miscible.

In the United States in 1916, 1917, and 1918, there were produced about 50,000,000 gallons of denatured alcohol. Much of the industrial alcohol is made to-day from sugar molasses and waste sulphite liquor. Garbage, fruit wastes and ethylene are suggested as auxiliary sources.

LIBERTY FUEL.—The so-called "Liberty Fuel," brought out in the United States during the war, is composed, as determined approximately by the Aeronautics Laboratories of the Army, of 65 per cent. benzol and 25 to 30 per cent. kerosene and the remainder amylacetate, which has a strong banana odor, and probably naphthalene and alcohol, with possibly small amounts of dissolved solids and other volatile liquids. Tests by the Bureau of Standards show that upon evaporation it left a heavy, gummy deposit, which hardened like varnish, consequently with its use the carburetor would soon become fouled. The initial boiling-point was found to be about 175° F., as compared with 140° F. for motor gasoline. It will not evaporate as readily, and starting would be difficult as compared with gasoline. Carbon deposits are said to be greater than with gasoline.

BENZOL.—This fuel is made from the distillation of coal tar. It was first recovered as a by-product in the manufacture of illuminating gas. Abroad it has been used as a fuel for omnibus and taxi engines. Commercial "90 Benzol" consists chiefly of benzene mixed with a small percentage of other coal-tar derivatives. In Europe a mixture of 50/50 benzol and alcohol has been used with excellent results as an engine fuel. It has also been used in aviation engines.

The coal refining industry has up to this time been slow in developing in the United States, approximately only about one-twelfth of the bituminous coal being brought into use, the remainder being consumed raw. The coke industry and the artificial gas industry are mainly responsible for the advance noted.. Benzol production and also the production of its

Fuel	Time required for complete evaporation of 10 cubic centimeters
Pure gasoline (68° grav.)	57 minutes
Gasoline + 5 per cent. benzol	60 minutes
Gasoline + 10 per cent. benzol	67 minutes
Gasoline + 20 per cent. benzol	86 minutes
Gasoline + 25 per cent. benzol	106 minutes
Gasoline + 30 per cent. benzol	111 minutes
Gasoline + 40 per cent. benzol	114 minutes
Gasoline + 50 per cent. benzol	116 minutes
Gasoline + 60 per cent. benzol	118 minutes
Gasoline + 70 per cent. benzol	119 minutes
Gasoline + 80 per cent. benzol	123 minutes
Gasoline + 90 per cent. benzol	139 minutes
Pure or 100 per cent. benzol	143 minutes
Pure toluol	555 minutes
Motor alcohol (95 per cent.)	270–300 minutes
Sulphuric ether	38 minutes

NOTE. Time of evaporation increases rapidly until 25 per cent. benzol is reached, and beyond this percentage up to 80 per cent. the rate of evaporation increases more slowly. A small percentage of toluol is very effective in reducing volatility and depressing the freezing point. Pure benzol is practically uniform in evaporation rate.

related products is mainly dependent upon the progress attained in coal refining. In 1918 the output of benzol in the coke industry, where by-product practice is replacing the bee-hive oven, in which latter the benzol and other by-products are not recovered, was 44,000,000 gallons. If by-product ovens were used throughout the coke industry, the output of benzol would be doubled, but would then have equaled scarcely 2 per cent. of the gasoline produced in 1919. In 1918, the artificial gas industry is credited with having produced 4,400,000 gallons of benzol, recovered from gas plants operating by-product recovery. The artificial gas industry consumes less than 2 per cent. of the United States consumption of bituminous coal. Even with benzol extracted from the bulk of the American bituminous coal on the basis of two to three gallons per ton, the supply would not be a factor.

The table on page 203 gives the relative results obtained from pure gasoline for various proportions of gasoline and benzol.

It is stated that in city traffic an average car using benzol averages 5 per cent. more mileage per gallon than with gasoline. In suburban and country driving, 10 per cent. to 15 per cent. is an average increase with benzol, and with continuous running less carbon is formed and there is less tendency to foul the spark plugs. Benzol vaporizes more slowly than gasoline, and gives a heavy, sluggish vapor, that does not mix rapidly with air. Benzol fed through an ordinary gasoline carburetor, at ordinary temperatures, manifold velocities, or temperatures, will enter the engine cylinder partly in the form of fine drops, which will require a greater length of time for their complete combustion. This condition is evidenced by the strong odor of benzol (unconsumed) at the end of the engine's exhaust pipe and by carbon formation in the exhaust pipes and mufflers.

A greater ratio of air to gas must be used for benzol to obtain a given percentage of CO_2 (carbon dioxide) in the exhaust gases as compared to gasoline.

With proper ignition and vaporization benzol can be made to show a very good economy. Several engineers are now working on the development of a benzol carburetor.

A series of road tests made in Germany during the latter part of the war with a standard Benz 16-horse-power car, using a fuel of 33 per cent. benzol and 67 per cent. alcohol, gave the following results:

Fuel	Miles per H.	Miles per gallon
Pure gasoline (56° B).	44	28.80
Pure benzol.	42	30.32
50 per cent. benzol, 50 per cent. alcohol	42	37.28
33 per cent. benzol, 67 per cent. alcohol	41	35.76

DISTILLATE.—This fuel is usually produced from Western Crudes, which contain a small amount of illuminating oil. It requires about the same amount of preheat as does benzol for its successful use. Its boiling-point is between a medium-grade gasoline and an illuminating oil. It is widely used in the West in tractor engines.

GASOLINE SPECIFICATIONS, U. S. GOVERNMENT, GRADE "M" MOTOR FUEL, REVISED SPECIFICATIONS, COMMITTEE ON STANDARDIZATION OF PETROLEUM SPECIFICATIONS

PRELIMINARY CHANGES

1. The end point of gasoline to be raised to 225° C. (437° F.).
2. The 90 per cent. point of gasoline to be raised to 190° C. (374° F.).
3. The reading at the 45 per cent. point to be replaced by the reading at the 50 per cent. point, and the temperature raised 5° C. (9° F.).
4. All reference to gravity to be eliminated from all specifications for lubricating oils.

REVISED SPECIFICATIONS FOR MOTOR GASOLINE

QUALITY.—Gasoline to be high grade, refined and free from water and all impurities, and have a vapor tension not greater than 10 pounds per square inch at 100° F. temperature, same to be determined in accordance with the "current rules and regulations for the transportation of explosives and other dangerous articles by freight," as issued by the Interstate Commerce Commission.

INSPECTION.—Before acceptance the gasoline will be inspected. Samples of each lot will be taken at random. These samples immediately after drawing will be retained in a clean, absolutely tight closed vessel and a sample for test taken from the mixture in this vessel directly into the test vessel.

SPECIFICATIONS

(*a*) Boiling-point must not be higher than 60° C. (140° F.).

(*b*) Twenty per cent. of the sample must distil below 105° C. (221° F.).

(*c*) Fifty per cent. must distil below 140° C. (284° F.).

(*d*) Ninety per cent. must distil below 190° C. (374° F.).

(*e*) The end or dry point of distillation must not be higher than 225° C. (437° F.).

(*f*) Not less than 95 per cent. liquid will be recovered in the receiver from the distillation.

TEST.—One hundred cubic centimetres will be taken as a test sample. The apparatus and method of conducting the distillation test shall be that adopted by Sub-Committee XI of Committee D-1 of the American Society for Testing Materials, with the following modifications:

First, the temperature shall be read against fixed percentage points, and, second, the thermometer shall be as hereinafter described:

FLASK

The flask used shall be the standard 100 c.c. Engler flask, described in the various textbooks on petroleum. Dimensions are as follows:

DIMENSIONS OF FLASK

Dimensions	CM	Inches
Outside diameter of bulb	6.5	2.56
Outside diameter of neck	1.6	0.63
Length of neck	15.0	5.91
Length of vapor tube	10.0	3.94
Outside diameter of vapor tube	0.6	0.24

Position of vapor tube, 9 cm. (3.55 inches) above the surface of the gasoline when the flask contains its charge of 100 c.c. The tube is approximately in the middle of the neck. The observance of the prescribed dimensions is considered essential to the attainment of uniformity of results.

The flask shall be supported on a ring of asbestos having a circular opening 1¼ inches in diameter; this means that only this limited portion of the flask is to be heated. The use of wire gauze is forbidden.

CONDENSER

The condenser shall consist of a thin-walled tube of metal (brass or copper) ½-inch internal diameter and 22 inches long. It shall be set at an angle of 75° from the perpendicular and shall be surrounded with a cooling jacket of the trough type. The lower end of the condenser shall be cut off at an acute angle and shall be curved down for a length of 3 inches. The condenser packet shall be 15 inches long.

THERMOMETER

The thermometer shall be made of selected enamel-backed tubing having a diameter between 5.5 and 7 mm. The bulb shall be of Jena normal or Corning normal glass, its diameter shall be less than that of the stem and its length between 10 and 15 mm. The total length of the thermometer shall be approximately 380 mm. The range shall cover 0° C. (32° F.) to 270° C. (518° F.), with the length of the graduated portion between the limits of 210 to 250 mm. The point marking a temperature of 35° C. (95° F.) shall not be less than 100 mm. nor more than 120 mm. from the top of the bulb. For commercial use, the thermometer may be graduated in the Fahrenheit scale.

The scale shall be graduated for total immersion. The accuracy must be within about 0.6° C. The space above the meniscus must be filled with an inert gas, such as nitrogen, and the stem and bulb must be thoroughly aged and annealed before being graduated.

SOURCE OF HEAT IN GASOLINE DISTILLATION

The source of heat in distilling gasoline may be a gas burner, an alcohol lamp or an electric heater.

PROCEDURE AND DETAILS OF MANIPULATION IN CONDUCTING DISTILLATIONS

1. If an electric heater is used it is started first to warm it.

2. The condenser box is filled with water containing a liberal portion of cracked ice.

3. The charge of gasoline is measured into the clean, dry Engler flask from a 100 c.c. graduate. The graduate is used as a receiver for distillates without any drying. This procedure eliminates errors due to incorrect scaling of graduates and also avoids the creation of an apparent distillation loss due to the impossibility of draining the gasoline entirely from the graduate.

4. The above-mentioned graduate is placed under the lower end of the condenser tube so that the latter extends downward below the top of the graduate at least 1 inch. The condenser tube should be so shaped and bent that the tip can touch the wall of the graduate on the side adjacent to the condenser box. This detail permits distillates to run down the side of the graduate and avoids disturbance of the meniscus caused by the falling of drops. The graduate is removed occasionally to permit the operator to ascertain that the speed of distillation is right, as indicated by the rate at which drops fall. The proper rate is from 4 c.c. to 5 c.c. per minute, which is approximately two drops a second. The top of the graduate is covered, preferably by several thicknesses of filter paper, the condenser tube passing through a snugly fitting opening. This minimizes evaporation losses due to circulation of air through the graduate and also excludes any water that may drip down the outside of the condenser tube on account of the condensation of the ice-cooled condenser box.

5. A boiling stone (a bit of unglazed porcelain or other porous material) is dropped into the gasoline in the Engler flask. The thermometer is equipped with a well-fitted cork and its bulb covered with a thin film of absorbent cotton (preferably the long-fibred variety sold for surgical dressing). The quantity of cotton used shall be not less than 0.005 nor more than 0.010 g. (5 to 10 milligrams). The thermometer is fitted into the flask with the bulb just below the lower level of the side neck opening. The flask is connected with the condenser tube.

6. Heat must be applied that the first drop of the gasoline falls from the end of the condenser tube in not less than five or more than ten minutes. The initial boiling-point is the temperature shown by the thermometer when the first drop falls from the end of the condenser tube into the graduate. The operator should not allow himself to be deceived as sometimes (if the condenser tube is not dried from a previous run) a drop will be obtained and it will be some time before a second one falls; in this case the first drop should be ignored. The amount of heat is then increased so that the distillation proceeds at a rate of from 4 c.c. to 5 c.c. per minute. The thermometer is read as each of the selected percentage marks is reached. The maximum boiling-point or dry-point is determined by continuing the heating after the flask bottom has boiled dry until the column of mercury reaches a maximum and then starts to recede consistently.

7. Distillation loss is determined as follows: The condenser tube is allowed to drain for at least five minutes after heat is shut off, and a final reading taken of the quantity of distillate collected in the receiving graduate. The distillation flask is removed from the condenser and thoroughly cooled as soon as it can be handled. The condenser residue is poured into a small graduate or graduated test tube and its volume measured. The sum of its volume and the volume collected in the receiving graduate subtracted from 100 c.c. gives the figure for distillation loss.

SECTION 4f

PETROLEUM LUBRICANTS AND OTHER PRODUCTS

TESTS OF TYPICAL CALIFORNIA LUBRICATING OILS.—The following tests are of oils made from California Crudes and illustrate the characteristic tests of these oils:

Type	Baumé gravity	Flash	Fire	Viscosity Saybolt at 100° Fahr.	Viscosity Tagliabue at 70° Fahr.	Color	Cold test
Pale.....	21–22	295–310	350–380	100–120	125–140	3–3½	0° F
Pale.....	20–21	310–330	360–385	145–150	190–220	3–3½	0° F
Pale.....	19–20	320–340	370–400	200–210	280–300	3–3½	0° F
Red.....	19–20	320–340	370–400	200–210	280–300	4–5	0° F
Red.....	18–19	370–380	430–450	850–950	1400–1600	8	0° F
Red.....	18–19	326–360	390–420	300–330	480–520	6	0° F
Red.....	18–19	350–365	400–430	410–450	650–700	6	0° F
Pale.....	19–20	330–350	365–400	325–360	515–590	4	0° F
Pale.....	20–21	300–320	360–385	130–145	175–200	3	0° F

TYPICAL TESTS OF LUBRICATING OILS MADE FROM SOUTHERN BASE CRUDES.—The following general tests are typical:

Gravity	Flash	Fire	Cold test		Viscosity Saybolt		Viscosity Engler		
					at 70° F.	at 100° F	at 70° C	at 50° C	at 20° C
20	340	380	0° F	......	270	......	....	3.3	....
20	345	390	0° F	Pale	330	......	....	3.69	....
20.2	340	380	0° F	Red	200	......	....	....	....
20	340	380	0° F	Pale	200	......	....	2.80	13.15
18½	360	405	0° F	Red	780	......	....	6.5	....
19	350	400	0° F	Red	560	......	....	....	36.52
21	300	345	0° F	Pale	100	......	.. .	2.0	6.34

Gravity	Flash	Fire	Cold test		Viscosity Saybolt		
					At 100° F.	At 150° F.	At 212° F.
22	325	360	0° F	......	137	57	39
20	330	380	0° F	......	215	75	43
19½	330	370	0° F	......	245	73	44
21½	335	380	0° F	... ..	205	68	41
21	350	400	0° F	......	300	84	46
19½	355	420	10° F	......	497	118	50

TYPICAL TESTS OF FILTERED CYLINDER STOCKS.—The following tests are given as typical:

Gravity	Flash	Fire	Viscosity Saybolt at 212° Fahr	Cold test	Name
26½	530	600	130	80–90	Filtered 600 stock.
26	550	640	150	50–60	Cold test filtered stock.
27½	540	600	145	40–50	Franklin, FFF, light-filtered stock.
29	450	525	90	70–80	
26	520	595	140	60	Medium filtered cylinder stock.

TYPICAL TESTS OF UNFILTERED CYLINDER STOCKS.—The following tests are merely typical tests, but are illustrative of the characteristics of these oils:

Gravity	Flash	Fire	Viscosity Saybolt at 212° Fahr.	Cold test	Name
23½	625	710	575	40–60	High flash stock superheat cylinder.
25½	600	690	200	40–60	Locomotive cylinder stock
25½	535	600	145	40	Steam refined 600 stock
22.5	585	650	235	42	

TYPICAL TESTS OF BLACK OILS.—The following tests are representative of tests of the black oils of several refiners:

Gravity	Flash	Fire	Viscosity Saybolt		Cold test	Name
			At 130° F.	At 212° F.		
25.0	430	...	....	65	25/60	Summer black.
19.0	365	...	....	90	25/60	Summer black.
21	400	...	....	95	25/40	Summer black.
23½	375	...	130–140	..	0/9	Winter black.
29	320	...	....	35	15	Fifteen cold test oil
28	350	400	102	50	5	Black car, 15 C. T.

TYPICAL TESTS OF PARAFFIN OILS.—The following table gives some typical tests of paraffin lubricating oils for the purpose of showing their characteristic tests:

Gravity B.	Flash	Fire	Cold test	Viscosity Saybolt At 70° F.	At 100° F.	At 150° F.	At 212° F.
24.5	420	...	35	410	305	103	51
28	355	...	28	100	100	..	..
29.5	345	...	25	80	80	..	..
26.8	375	...	30	180	155	66	40
24.5	415	...	32	385	295	96	50
31.3	330	...	25	60	65	..	..
26.0	390	...	30	200	170	68	43
25.5	390	...	30	260	212	80	44
25.0	410	...	32	300	230	80	47
24.0	410	...	30	360	...	..	..
25.0	390	...	35	...	180	73	43

TYPICAL TESTS OF NEUTRAL OILS.—The following table gives some typical tests of bone-filtered neutral oils:

Gravity	Flash	Fire	Cold test	Viscosity Saybolt At 70° F.	At 100° F.	Color
32	390	440	25	145	...	No. 1
36	275	325	20	45	...	No. 1½
34	325	375	25	70	...	No. 1
30	400	450	25	155	...	No. 5
31.5	330	375	25	60	63	
31	400	...	30	...	180	
28.0	405	...	25	210	185	
30	400	...	23	185	170	
31	365	...	25	90	90	
30½	390	...	20	150	140	

The following table is based upon tests of so-called "Western Neutrals."

Color	Gravity	Saybolt Viscosity	Flash	Fire	Cold Test
3	28.4	140/145 at 100	370	430	25-35
3	27.4	160/180 at 100	370	430	20-25
3	27.0	200 at 100	385	440	20-25
3½	26.3	250 at 100	395	455	20-25
6	26.5	225/235 at 100	390	450	25-35
6	25.8	280/290 at 100	400	460	25-35
5/6	26.3	240 at 70	315	360	20-25

TYPICAL TESTS OF LUBRICATING OILS MADE FROM BRADFORD, PA., CRUDE OIL. THE NEUTRALS ARE FILTERED AND NOT ACID-TREATED. COLORS ARE NATIONAL PETROLEUM ASSOCIATION COLORS

Type	Color	Flash Fahrenheit	Fire Fahrenheit	Gravity Beaumé	Cold Fahrenheit	Viscosity Saybolt
Viscous neutrals	No. 3	375	440	30.4	15	150 at 70
	No. 3	400	450	30.2	20	180 at 70
	No. 3	410	475	30	20	200 at 70
Non-viscous Neutrals.......	No. 3	370	420	32	15	90 at 70
	No. 2	335	390	34	10	55 at 70
Machine oil....	Green	415	480	29.4	20	295 at 70
	Green	430	490	29	15	400 at 70
	Green	440	500	28.5	15	700 at 70
	Red transmitted	390	440	29.9	26	150 at 70
	Green reflected	410	470	29.4	24	300 at 70
Steam refined Cylinder stocks	Green	535	600	26	40	160 at 212
	Green	545	610	25.5	40	168 at 212
	Green	570	635	25	30	200 at 212
	Green	590	650	24.5	30	225 at 212
	Green	600	675	24.5	30	250 at 212
Black oils......	Black	410	475	23.5	10	55 at 212
	Black	490	550	22.5	20	83 at 212

SPECIAL OILS AND PRODUCTS

BELT DRESSINGS.—Belt dressings are used to soften belts and to improve their surfaces. They are usually made of waxes, degras, solid fat, acidless tallow (70 per cent.) and castor oil or fish oils (30 per cent.).

Sometimes they are made with corn oil, or treated with sulphur chloride, mineral oil added and thinned with naphtha. Some dressings contain resin, which is objectionable.

There are two classes of belt dressings. One class is designed to re-lubricate the leather fibres, and the other is designed to make the belt adhere to the pulley, thus permitting it to be heavily overloaded. The usual product for currying leather belting is made with a mixture of tallow and cod oil, the proportions of tallow and cod oil being various, according to the atmospheric temperature and the hardness of the tallow. While mineral oil has been added to some extent by some manufacturers to the tallow and cod oil, the best practice eliminates the mineral oil constituent and uses only the tallow and the cod oil. A mixture of tallow and cod oil is not a marketable proportion, as it tends to slowly decompose and become crystalline, and is very susceptible to temperature changes.

Neatsfoot oil is also a desirable leather belt lubricant, and produces a good traction surface on the grain and penetrates quickly, lubricating the fibres. The oil should be of first grade purity and not be applied to the belt in excessive quantities, or it will cause stretch and sogginess.

Castor oil is extensively used as a belt dressing. It penetrates well, but not as quickly as Neatsfoot oil, and tends to leave a slight deposit on the belt surface, which increases the friction between the leather and the pulleys.

Mineral oil is not recommended for use in any considerable proportions in making belt dressings, for while it is not definitely established as to what is the cause of the bad effect of the mineral oils upon the leather, it is known that lubricating oils, dripping onto a belt, impair its wearing qualities.

Some belt dressings carry substances, such as tar, asphalt, petroleum, pitch, resin, etc., and materials which have a more or less resinous nature. Resinous substances tend to cause the leather fibres to grip one another tightly and bring on stretching, which is opposite to the effect desired. While these substances will cause a belt to adhere to the pulley surface, nevertheless they cause a drag, due to the power required to pull the belt away from the pulley. The resinous materials also penetrate the leather fibres, and when they become dry, leaving no lubricating values, they tend to cause the fibres to tear themselves to pieces and shorten the life of the belting.

* **MEDICINAL OIL.**—In the past, Russian oil was largely imported for the purpose of supplying the trade with an oil to be used by the medical profession for spraying the throat and nasal passages and for taking internally for the relief of constipation. With the discovery of the immense benefits to be obtained by the use of petroleum oil in the treatment of constipation and after considerable experiment with oils from American Crudes for these purposes, there are several highly efficient medicinal oils made from these crudes now on the market. A typical oil

* U. S. P. calls for .870 specific gravity or heavier for white medicinal oil.

would have the following tests: Gr. 34–35, Fl. 340–350, Vis. 88–90 @ 100 F., Pour 20–25, Iodine value below 0.85. These oils are very highly filtered and treated. The bloom or cast is removed.

APRON DRESSINGS.—In some localities there is a demand for apron dressings. They are usually made up of about 7½ per cent. to 8 per cent. of No. 1 Neatsfoot oil, 2 per cent. elaine, and the remainder of a neutral or treated neutral petroleum oil of about 50 Vis. @ 100 F. Apron oil may also be made from a wool stock, lard oil and degras, using from 80 per cent. to 95 per cent wool stock and 5 per cent. to 20 per cent. degras and No. 1 lard oil.

HARNESS OIL.—For this purpose a good oil can be made by using a good-bodied paraffin oil of about 25 to 27 Gr. and 175 to 190 Vis. @ 100° F. About 5 per cent. of aniline dye is sometimes added.

CURRIER'S OIL.—Oil for this purpose should have a Vis. of about 275 to 300 at 100° F. A red paraffin oil may be used, or an asphalt-base oil.

DUST-LAYING OILS.—These oils usually consist of petroleum asphalt, in solution in oils similar to gas oils. The basic idea in their manufacture is that the solvent will slowly evaporate, leaving the dust particles covered with a sticky, adherent film.

ROAD BINDERS.—They consist usually of petroleum asphalt, fluxed with heavy oils which will not evaporate and of such quantities that they will bind the road-making materials together. They should act equally well in winter and summer.

GAS OILS.—These oils are usually of all degrees of volatility, depending upon refining conditions. The most economical for the gas-maker are said to consist of a mixture of heavy hydrocarbons with an average boiling-point of about 60° F. They should not contain gasoline or lamp oil on one hand and should be free from heavy lubricating oils on the other hand. They should be free from asphalt. (See index, "Gas Making.")

CONCRETE FORM OIL.—This is usually a neutral of about 34–35 Grav. and 80 Vis. Say. at 100° F., 20° to 25° F. C. T., or a 28° paraffin oil.

FOAM OIL.—This oil is used in paper mills. It is usually a 45° burning oil and a 300° mineral seal oil.

OIL PULP OR THICKENER.—Some lubricating oils are artificially thickened with oil pulp. A very small quantity of this oil pulp melted into a mineral oil will increase its viscosity greatly. Oils made in this manner can usually be easily recognized because of their tendency to pull out in long threads when the cork in a bottle containing them is removed. They are usually of the appearance of oil and jelly. The increased viscosity obtained by the use of the thickener is subject to rapid reduction when the oil is subjected to heat. Sometimes lime soap is used as a thickener, but generally oil pulp consists of aluminum soap, consisting of aluminum salts of fatty acids, chiefly oleic, palmitic and stearic acids.

The aluminum soap is made by saponifying cottonseed, lard or whale oil with caustic soda and then pouring this soda soap into an alum solution, combined with stirring.

BATCHING OIL.—A typical batching oil tested 25 to 28 B. Grav. and 88–100 Vis., say, at 100° F.

STRAW OIL.—A "straw oil" tested had the following tests: 28–31 B. Grav., 58–65 Vis. Say. at 100° F.

SECTION 4g

LUBRICATING GREASES

GREASES

GREASE, GENERAL.—There are several different methods of making grease, as follows:

(*a*) Fire cooked.
(*b*) Steam cooked, or boiled.
(*c*) Semi-boiled.
(*d*) Cold set.
(*e*) Double decomposition.

Lubricating grease is a metallic soap mixed with a mineral oil. A metallic soap is a metallic base and a fatty acid radical. The principal soaps used in grease manufacture are: Lime soap, aluminum soap and sodium soap, and in some cases potassium soap.

The fats and fatty oils that are used in grease manufacture contain:

Stearin: $C_3H_5(C_{18}H_{35}O_2)_3$ or (glyceryl sterate).
Olein: $C_3H_5(C_{18}H_{33}O_2)_3$ or (glyceryl oleate).
Palmatin: $C_3H_5(C_{16}H_{31}O_2)_3$ or (glyceryl palmitate).

The operation of making soap is called "saponification."

In explanation of the formulas, the letters given are symbols, representing the following elements:

C = Carbon.
H = Hydrogen.
Ca = Calcium.
O = Oxygen.
K = Potassium.
Na = Sodium.

When oils or fats are heated with caustic soda ($NaOH$), caustic potash (KOH) or lime (CaOH), the soda, potash or calcium takes out the fatty acid or acids from the oil or fat. The product thus obtained from soap and the so-called basic "radicle" (C_3H_5), glyceryl, is separated out in the form of glycerin.

To convert a fat into a soap, one method is to add caustic soda (lime or potash is also used for this purpose). The lime soap gives a soap that is insoluble in water, while the soda and potash soaps are soluble in water.

The formula obtained when caustic soda is added to the fat is given in the following formula, as follows:

$$\overbrace{3NaOH}^{\text{Caustic Soda}} + \overbrace{C_3H_5(C_{18}H_{33}O_2)_3}^{\text{Fat}} = \overbrace{3NaC_{18}H_{33}O_2}^{\substack{\text{(Sodium Oleate)}\\ \text{Soap}}} + \overbrace{C_3H_5(OH)_3}^{\text{Glycerin}}$$

FIRE-COOKED GREASE.—When a soda soap is made, it contains about 40 per cent. of water, and when the water is taken out there remains a product having the appearance of a chemical compound similar to magnesia and which looks like lime. If a fibre grease is to be made, sodium sterate is used.

Since better saponification is obtained with high temperature, soda grease is made in a fire kettle, otherwise considerable water would be left in the soap, if steam were used for heating, and the grease would not have as high a melting-point.

FIBRE GREASE.—The fire is charged under the kettle and a small amount of mineral oil is put into the kettle to soften the soap. When the soap is melted the mineral oil is very slowly added until all of the oil has been added. It is well to note that if the grease is allowed to cool too quickly the grease will "gelatine." The temperature to start should be about 400° F., and when all of the oil has been added the temperature should be about 220° to 250° F., which will give the product a fibrous appearance. Slow cooling and constant agitation give a fibre grease.

After the oil has been added and the batch is finished, it is run into a cooler, where it is agitated for about five or six hours, which helps to make the fibre better and the grease more uniform; while if only a small amount of agitation was used a gelatinous product unlike fibre grease would be obtained. The fibre grease is then barreled. Steam-cooked grease can be used, but better results are obtained by fire cooking.

CUP GREASE.—In making lime-soap cup grease, an amount of mineral oil is added to the soap and the solution of milk of lime and fat. This is heated until practically all of the water is evaporated, which gives a lime soap. Lime soap, when properly made, will be softer when cold than a corresponding grease, due to the mixture being necessary in the grease to form an emulsion to bind the oil and soap together. It is necessary, for this reason, to cool the soap down before adding water to form the emulsion. When the water is added to the soap it gives it a semi-liquid appearance. After this operation is completed the mineral oil is slowly added. The reason for adding the oil slowly in this case is not the same as in the case of making a fibre grease, which was to form the fibre, but it is because of the tendency of the soap to separate or drain; since if the oil is added too fast some will stay on top and some will go through, thus not taking the oil well or making a good emulsion. If this separation begins, it is very hard to stop it. In some cases, depending upon the kettles and the emulsion, it can be remedied by steam and sometimes by cooling; but generally in either case when making a lime-soap grease, if separation starts, it will not be possible to get as homogeneous a grease as would have been produced if the soap had taken up the oil in the first place.

The best practice is to next pump the grease out through the bottom of the kettle by means of rotary pumps, through a 40-mesh screen to remove the lumps. (Some plants use 20-, 40- and even 60-mesh screens.) In the older practice, the grease was run out through an open strainer of about 20- or 25-mesh screen, at about 180° F.; but this method produced considerable cooling when the grease came down through the strainer, which left a lot of grease sticking to the sides.

It is necessary to strain grease, because in thinning down soap with

mineral oil there is more or less soap which becomes cold at the sides, and which would drop as lumps into the flow, and as these lumps would not be taken up again, the grease would contain a small amount of suspended soap. The finer the sieve the more of the undissolved soap it will remove.

The lime used should be 95 per cent. pure, and should show no lumps in a 40-mesh sieve. Lime is likely to have an unburned residue.

In the best grades of grease a good grade of oil, having about 180 Vis. Saybolt at 100° F., is used, while in the cheaper grades a 28° paraffin oil of about 90 Vis. is used. In the very inferior greases a cheap gas oil, having only about 50–65 Vis. Say. at 100° F., may be used.

SEMI-FLUID GREASES.—A batch of cup grease as above described is first made, it is then strained over into a cool cylinder to bring down the temperature, and then sufficient mineral oil is added to give the various grades desired. The greater the percentage of oil the more fluid the grease. They are usually steam-cooked. Great skill is required to produce a semi-fluid grease which will maintain the desired consistency and which will not settle and separate. Lime soap, and for the best grades a 25° paraffin oil are used.

Greases of this nature are made by a well-known manufacturer, which show no separation after standing for many months, and even for several years. The percentage of moisture in the grease has an important bearing upon this factor. If more moisture is used, it may stop the tendency to change, but it would give a grease that is not as clear. If the grease stands in a warm room, causing the moisture to leave it, it may result in some separation.

STEAM-COOKED OR BOILED GREASE.—Steam kettles are used. These kettles slightly taper in at the bottom, so that the bottom diameter is about a third smaller than the top diameter. A shaft, equipped with three pairs of arms, is put into the centre of the kettle, and is turned by bevel gears, so that the grease can be worked. The steam is passed around the kettles in steam jackets.

SEMI-BOILED GREASE.—These greases are generally known as "engine greases." They contain a high percentage of fat, usually tallow, with a small percentage of paraffin oil, to give the different consistencies. These greases are heated sufficiently to make an emulsion. Caustic soda ($NaOH$) is used as a saponifying agent. Ten to 15 per cent. of this solution is used. Very little water is boiled out. These greases are sometimes called "tallow greases." They contain about 10 per cent. water, 40 per cent. to 50 per cent. of tallow and a small percentage of mineral oil, the principal ingredient being tallow.

These greases must be very carefully made, and one of the most important points to be watched is the cooling of the kettle after enough mineral oil has been added to give the soap the desired consistency. Often these greases, if carelessly made, contain an excess of soda, and will absorb carbonic acid from the air, causing pitting of the bearings on which they are used. If the grease contains too little soda, free fatty acids will be present and trouble will also result.

They are usually very much harder than the other greases.

If free alkali is suspected in these greases, dissolve a very small

amount of the grease in boiling water and test with a piece of red litmus paper. If it turns blue, free alkali is present. The rapidity with which the paper turns color is an indication of the amount of the free alkali present.

COMPOUNDED GREASES.—Compounded greases are really only a mixture of animal, mineral and vegetable oils with their waxes.

Compounded greases tend to turn rancid in standing, due to oxidation, and will, therefore, attack metals. Very often they are loaded with paraffin or other waxes which are not lubricants, and, therefore, tend to add to the bearing friction rather than reduce it.

COLD-MADE GREASE (COLD SET).—This type of grease is used for axle, curve grease and other kindred purposes. They are usually very cheap.

In a general way, the method of making these greases is as follows: Resin oil is added to a mixture of mineral oil and slaked lime. The resin oil is called the "Set," and the mixture will, after being well stirred, become solid or plastic, according to the amount of the resin oil or "set" that has been added. Within a few minutes after the mixture is made the resin acids and the lime interact and form a soap.

Sometimes these greases are lumpy and not smooth; this condition may be caused by not filling the containers on a firm floor free from vibration, or by trying to move the packages before the grease has had time to set. The greases may also show signs of separation if they contain an excess of water.

It is necessary to add a large amount of lime for the reaction. The lime is also intended to act as a filler. Generally 28° paraffin oil and cheap lime are used. The grease is usually made in the barrel in which it is to be shipped.

DOUBLE DECOMPOSITION GREASE.—A typical double decomposition grease is "Castor Machine Oil."

The method of making this type of grease is as follows: Since it is not possible to saponify a fat and aluminum, a solution of soda soap is first made, and then a solution of alum and aluminum sulphate. When these are put together they form an insoluble compound (aluminum soap). This solution is then put into a kettle and mineral oil is added and dissolved. It is known as "Oil Pulp." It is then heated to drive off the water and becomes very gelatinous and stringy. Many kinds of grease can be made this way.

MANUFACTURING TESTS.—It is generally considered to be too much trouble to test soaps in the laboratory for every oil. In a lime grease it is not possible to have a set formula. Sometimes a little more fat is required and sometimes a little more lime. The soaps must be perfectly neutral and should be soft and pliable. If the soap contains an excess of lime and is allowed to get cool, it will become hard and will crumble, and in this case more oil must be added to bring the soap smooth again. Some days oil will be taken up by a soap more readily than on others.

The grease should be tested for consistency before barreling. It is usually done by taking a sample from the kettle and immersing it in ice water for about 15 minutes, and while grease cooled in this way does not feel the same nor have the same consistency as if allowed to cool slowly,

the general character of the finished grease may thus be judged. The sample can be tested on the consistometer. More or less water in the grease gives it a different appearance, causing a difference in color.

Grease loaded with animal or vegetable products will have a very brittle structure.

FILLERS.—Some unscrupulous grease manufacturers weight their greases with a "filler." These fillers may consist of wax, resin, talc, or some other substance equally worthless as a lubricant.

FAT, ASH AND SOAP CONTENT, CUP GREASES.—A typical well-made cup grease has the following characteristic tests:

	Percentage of Calcium Soap Made from an Approved Fat.	
Total Soap—		
No. 1/2 cup grease	Approx. 13	per cent.
No. 1 cup grease	Approx. 14	per cent.
No. 3 cup grease	Approx. 16–18	per cent.
No. 5 cup grease	Approx. 24–26	per cent.
Ash—		
No. 1/2 cup grease	Approx. 1.7	per cent.
No. 1 cup grease	Approx. 1.8	per cent.
No. 3 cup grease	Approx. 1.8–2.3	per cent.
No. 5 cup grease	Approx. 2.5–3.5	per cent.

Soap gives body and melting-point. Most greases contain about 3 per cent. free tallow.

LEAD SOAP IN GREASE.—For some greases, particularly those used for transmissions and worm-gear lubrication, where a very unctuous grease is required, a lead soap is used instead of a soda or a calcium soap. A grease of this character will resist the scraping, squeezing action of a worm and gear. Lead-soap greases do not emulsify with water.

NAVY DEPARTMENT SPECIFICATIONS (14 G. 1b., 1916)—MINERAL LUBRICATING GREASE

COMPOSITION

2. Mineral lubricating grease shall be a homogeneous mixture consisting exclusively of from 80 to 90 per cent. of mineral oil and the remainder an odorless lime soap made from clear animal fats and the proper amount of lime for saponification. It shall be free from fillers, uncombined lime, gritty substance, resin oil, resin, or resinates, and from mineral or fatty acids, alkalies, or any deleterious impurities, and shall not yield more than 2 per cent. of ash from medium grease, and not more than 3 per cent. of ash from hard grease. The grease shall lose not more than 2 per cent. of its weight when heated for one hour at 110° C. in a glass crystallizing dish containing about 10 grams of grease, in an air oven.

GRADES

3. (*a*) *Medium grease* shall flow at a temperature of from 75° to 80° C. when tested in a glass crystallizing dish containing about 10 grams of grease, heated in an air oven.

(*b*) *Hard grease* shall flow at a temperature of about 90° C. when tested in a glass crystallizing dish containing about 10 grams of grease, heated in an air oven.

LUBRICATING PROPERTIES

4. The grease shall possess lubricating properties determined by practical test in a lubricant-testing machine, as follows:

When fed at a rate not exceeding 1 1/2 grains per minute through a grease cup, on friction surface of a brass shoe having 9 square inches bearing surface, sustaining a load of 1926 pounds against a steel journal 6 inches in diameter, revolving at a surface velocity of 405 feet per minute, it shall maintain an even temperature of not more than 50° C. above surrounding normal temperatures, and the coefficient of friction shall be constant during the last hour of the run and shall not exceed 0.013.

GEAR COMPOUNDS.—Cheap inferior grades of gear compounds are made by mixing paraffin wax with a heavy mineral oil. Paraffin wax is not a lubricant. Good gear compounds are usually made by blending a mineral oil with a fibre grease.

GRAPHITE GREASES.—For certain cases where bearings are exposed to dampness, and where it is necessary to use a grease instead of an oil, graphite grease will give the best results. The addition of graphite tends to prevent the grease being washed from the bearing. A grease of this nature is often used on the exposed bearings of street railway cars.

Navy Department Specifications (14 G. 2b., 1916)—Graphite Lubricating Grease

GENERAL SPECIFICATIONS

1. General Specifications for Inspection of Material, issued by the Navy Department, in effect at date of opening of bids, shall form part of these specifications.

MATERIAL

2. Graphite grease to consist of 8 to 10 per cent. of amorphous graphite containing at least 82 per cent. of graphic carbon mixed with a mineral lubricating grease of the following composition and consistency: Mineral grease to be a homogeneous mixture consisting of from 80 to 90 per cent. mineral oil, and the remainder an odorless lime soap made from clean animal fats and the proper amount of lime for saponification. To be free from grit, resin, or resinates, and from mineral or fatty acids, alkalies, or any deleterious impurities. Medium grease to flow at a temperature of from 75° to 80° centigrade, and hard grease to flow at about 90° centigrade when tested in a glass crystallizing dish containing about 10 grams of grease, heated in an air oven. The grease to lose not more than 2 per cent. of its weight when heated for one hour at 110° centigrade and tested in a similar dish and oven.

LUBRICATING PROPERTIES

3. To possess lubricating properties, determined by practical test in Riehle bearing testing machine, as follows:

When fed at a rate not exceeding 2½ grains per minute through grease cup, on friction surface of a brass shoe bearing having 9 square inches bearing surface, sustaining a load of 1.926 pounds against a steel journal 6 inches in diameter, revolving at a surface velocity of 405 feet per minute, it shall maintain an even temperature of not more than 50° centigrade above surrounding temperatures, and the coefficient of friction shall be constant during the last hour of the run and shall not exceed 0.031 for medium grease and 0.04 for hard grease.

GREASE MELTING POINT.—In general, there is no accepted method for determining the melting point of a grease, although the grease manufacturers have adopted systems applying to their own products, but not directly comparable to other manufacturers' products. A method, described by Gillette (*Journal Industrial and Engineering Chemistry,* 1909, p. 351) is interesting; and while in itself the test means but little, however, when made in conjunction with a complete analysis of a grease, it is of value in checking up a manufacturer's products as to uniformity for successive lots of grease of the same grade. It also indicates, to some extent, the temperature at which the grease will function. The method, as outlined by Gillette, makes use of an open capillary tube, 4 mm. inside diameter and about 8 cm. long, graduated at 1 cm., and 5 cm. from one end. In making the test, this tube is inserted in the grease, and a plug of grease is drawn up 1 cm. into the tube. Suction is used, if necessary to drawn up this plug. The tube is then attached, with a rubber band, to a thermometer, so as to bring the grease plug beside the bulb. The thermometer and tube are then immersed in a beaker of water, so as to bring the bottom of the tube 5 cm. below the surface of the water. The water is then heated at the rate of about 3° per minute, and when the melting point is reached, the plug, which is under a pressure of 5 cm. head of water, flies up the tube. Of course, this test is dependent upon a number of factors, and is of value chiefly as an indicator. The nature and amount of soap, oil and water in the grease, as well as the process used in manufacturing the grease, affect the melting point.

The following tests made with this method, in conjunction with analysis of the grease, are given as an indication of results that may be obtained. The tests are from a paper by H. R. Trotter:

	Kind of soap base used in making grease	Mineral oil, per cent	Unsaponified fatty oil, per cent	Lime soap (calculated as calcium oleate), per cent	Soda soap (calculated as sodium oleate), per cent	Free lime, per cent	Free alkali (calculated as sodium hydroxide) per cent	Free acid (calculated as oleic acid), per cent	Moisture and undetermined, per cent	Melting point (Gillette method)
1	Soda soap grease	53.6	28.88	.....	5.17	.....	.....	0.14	12.21	108°F
2	Soda soap grease	98.13	0.6	.....	0.70	.....	.....	0.05	0.52	Fluid at room temperature
3	Soda soap grease	92.60	0.3	.....	6.10	.....	.....	0.06	0.94	110°F
4	Lime soap grease	88.31	1.55	8.15	.....	0.19	.....	0.07	1.73	103°F
5	Lime soap grease	84.56	0.10	10.72	.....	0.15	.....	0.04	4.43	190°F
6	Lime soap grease	74.49	2.03	17.94	.....	0.30	.....	0.08	2.16	170°F
7	Lime soap grease	67.26	0.42	27.18	.....	1.53	.....	0.05	3.56	210°F
8	Lime soap grease	82.0	4.72	10.72	.....	0.03	.....	0.07	2.46	151°F
9	Lime soda soap grease	90.44	0.53	6.80	0.77	0.04	0.006	.....	1.414	114°F
10	Lime soda soap grease	85.38	0.40	11.02	0.95	0.13	0.002	.....	2.118	192°F
11	Lime soda soap grease	78.00	3.95	14.34	1.52	0.57	0.004	.....	1.606	189°F
12	Lime soda soap grease	74.28	0.42	19.09	1.78	0.65	0.014	.....	3.76	205°F

STEAM CYLINDER GREASE.—Grease may be used as a steam cylinder lubricant. The grease is fed to the cylinder by means of a specially designed lubricator, which first melts the grease and then feeds it into the steam line, where it is atomized by the steam.

The usual cylinder grease on the market is composed of about 85 per cent. mineral oil and 15 per cent. tallow, the mineral oil component consisting of about 66 per cent. of a filtered cylinder stock and 33 per cent. petroleum grease.

There is no possible advantage in using a cylinder grease, and if its cost is compared with the ordinary, or even the highest, priced cylinder oil, it will be found that the grease is a very expensive proposition (figuring 7½ pounds of grease to the gallon of cylinder oil).

There are numerous claims made for the lubricators, loaned by the manufacturers of these greases, but none of these claims are borne out in practical use that could not be obtained with a well-regulated cylinder sight-feed lubricator.

PINION GREASES.—Pinion greases are usually made from residuum from the stills. It can be produced in various consistencies, from that of heavy cylinder oil to a grease so stiff that it must be warmed to cause it to flow. These greases have a high adhesive power and will stick to an exposed bearing under the most adverse conditions. The thinner bodied greases are frequently used as wire cable coatings. Usually a little pine tar is mixed with the grease during manufacture. Some pinion greases are entirely made from pine tar, but these greases do not possess the adhesive or lubricating qualities of the residuum grease.

* **PETROLEUM GREASE.**—Petroleum grease is a sort of amorphous wax. It is obtained as follows: When refining to cylinder stock, the residue in the still, which is a cylinder stock, is mixed with naphtha. This mixture is then allowed to settle, while being kept at a low temperature. The mixture separates into two parts, the lower being the petroleum grease, and the upper part is drawn off. This upper part is then heated to drive off the naphtha, which can be used again, and the remaining residue is a low cold-test cylinder stock.

The petroleum grease may be filtered to produce the different colored petrolatums. With some crudes, it is possible to obtain the petrolatum stock by straight refinement; that is, it remains as a residue in the still, after the lighter parts of the crude have been distilled off. These crudes are very few, however, and come from certain sections of Pennsylvania.

TALLOW GREASES.—The so-called "tallow greases" are usually made with some hard animal fat, in combination with a small amount of mineral oil. The mixture is solidified by the use of soap. Its melting-points are usually between 50° and 75° lower than the melting-point of the usual petroleum "cup grease."

STEARIC ACID.—Stearic acid, which may occur in a free state in inferior grease, attacks iron, steel, and all their alloys. For this reason great care must be used in selecting a grease.

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* NOTE. Sometimes called Petrola.

SOME USES AND TYPES OF GREASE

Grease is applicable to all forms of machinery, even to the lubrication of steam cylinders. However, grease lubrication has its own special field, where it has an advantage over oil lubrication. One of these fields is for machinery, where the operation is intermittent.

If well-designed grease cups are used, and filled with a grease of the proper density, the cups will require little attention, except to fill when empty. Waste is reduced.

Some of the main types of greases and their uses are as follows:

(*a*) Axle greases ....Carriage and wagon axles.
(*b*) Cup greases ....Used in compression cups, funnel cups, or in the bearing by packing.
(*c*) Gear greases ....Tacky, waterproof, grease for gears, racks, etc.
(*d*) Curve or track greases ...Applied with brush or dauber to railway-track curves.
(*e*) Launching grease ....Used on shipways.
(*f*) Tunnel-bearing grease ..Made in small blocks, about 56 pounds. Used in standard grease boxes, to lubricate shaft bearings of steamships.
(*g*) Semi-fluid grease ....Used in textile mills, high-speed machinery, etc.; also in mine cars.
(*h*) Steel-mill greases ....Cold-neck grease. Usually a cold-set resin grease. For roll necks running at ordinary temperatures.
Hot-neck grease: An adhesive, high-melting point grease, waterproof.
(*i*) Elevator greases ....Plunger grease: Waterproof, acidless grease. Must not injure rod packings.
Slide grease: Used on elevator slides. Usually No. 3 consistency graphited.
(*j*) Gear-shield grease, or pinion glaze ....Usually made in three consistencies, of different melting-points. Used in steel mills, etc., where gears are exposed to intense heat. The grease on cooling forms a cushion, which adheres to the gear. Usually the heavy grade requires melting before application to the gear.
(*k*) Railroad grease ....Rod grease. Usually hard. Used in driving-rod cups.
Driving-journal compound: Hard. Made to fit the grease boxes.
Wool-mixed grease: Made of long-fibre woolen yarn and a small percentage of cotton waste, impregnated with a high melting-point grease. Used for journal lubrication, instead of usual oil and waste.
Air-brake grease: Usually a graphited, waterproof grease.

(*l*) **Paper-mill greases**........Usually fibre type. High melting-point. Bearings are very hot, due to steam passing through them. Wool-mixed grease often used, or box is packed with wool, and from time to time fresh grease is added.

OIL PULP OR ALUMINUM SOAP.—Aluminum soap consists of the aluminum salts of fatty acids, chiefly oleic, palmetic and stearic acids. It is dissolved in mineral oils to form a thickener.

GRAPHITE

GRAPHITE.—Graphite exists in two forms: Flake and Amorphous. Crystalline graphite or Flake graphite is dense and compact and is not easily reduced by crushing between the fingers, so that the individual particles maintain their size. "Amorphous" graphite under pressure continues to be reduced in size until the particles are no longer evident to the touch. Flake graphite is the better lubricant, because it has good wearing qualities and adheres to metallic surfaces with which it comes into contact. Graphite is not affected by heat. The value of flake graphite as a lubricant lies in its property of filling any irregularities that exist in a bearing surface, thus reducing the roughness of the surface and producing a better surface for lubrication with oil or grease.

Graphite is of value as a lubricant for steam engine cylinders, provided it is used in great moderation and not fed in excess. The entire value of graphite as a lubricant is lost if an excessive amount is used.

When the valve seats and cylinder walls of an engine are badly cut or scored, the addition of a little graphite (several spoonfuls), mixed with the cylinder oil, will greatly aid in smoothing up the bearing surfaces.

For steam engine cylinders using superheated steam, flake graphite is of great value. It aids in filling up the irregularities of the cylinder wall surfaces, so that the cylinder oil, which is greatly reduced in viscosity by the high temperatures found in these cylinders, will have the best possible surface conditions to work on.

In order to obtain a clear idea of the value of graphite as a lubricant, the engineer must appreciate the fact that in order to be efficient, graphite must identify itself with the metallic surfaces to be lubricated. Its function is to fill up the pores and depressions in the surfaces, giving them a smooth polished finish. Lubricating oil must then be introduced between the rubbing surfaces so as to produce a film, which will be more efficient in its results because of the reduced frictional resistance to be overcome, due to the graphited surfaces.

The specific gravity of graphite is 1.81, and, therefore, is greater than that of oil, and for this reason it will settle out of oil on standing. It is not possible to permanently suspend graphite in oil. A mixture of oil and graphite should never be put in an oil cup or sight-feed lubricator, as the graphite will soon clog the feed passages.

For engine bearings a heaping teaspoonful of graphite to a pint of oil is sufficient.

About 4 per cent. by weight of graphite is the average good practice when mixed with oils and greases, and gives good results when applied at reasonably long intervals.

Graphite should never be used on bearings supplied with forced or flooded continuous lubrication.

NOTES ON GRAPHITE.—If a lubricant must be a non-conductor of electricity, graphite should not be used in its make-up, as graphite is a good conductor of electricity.

Graphite is not affected by high temperatures. It cannot become carbonized or ignited, and gives off no explosive vapors.

There is no advantage in permanently suspending graphite in oil from a lubricating standpoint, because the particles of graphite being in

perfect suspension cannot break through the surrounding film of oil, in order to become attached to a metallic surface.

DEFLOUCCULATED GRAPHITE.—A soft, unctuous, almost pure graphite was discovered by Doctor Acheson amongst the products of the electric furnace. He further discovered a method of treating this graphite with a vegetable extract and diluted it with water. It then acquired the property of remaining suspended in the water. The defloucculated graphite thus produced, after being allowed to remain in suspension in the water for a definite time, is filtered through a canvas filter that is impregnated with rubber films under pressure. The water is thus slowly separated, and a paste composed of deflouculated graphite and water is then obtained. This was given a trade name. Another product is obtained by working this paste with a lubricating oil, the water being gradually eliminated.

The latter product is used for lubrication, and the former has been used in connection with thread-cutting, boring and reaming, etc.; also in air compressors, etc.

SECTION 5

FATS AND OILS OTHER THAN PETROLEUM PRODUCTS

FATTY OILS

CHEMISTRY OF FIXED OR FATTY OILS.—Fixed or fatty oils are composed of fatty "esters," formed by the union of "alcohol radicles" with "fatty acid radicles." The alcohol radicle found in most animal oils and in the vegetable oils is the so-called "trivalent radicle," glyceril (C_3H_5). The radicle of glycerin or glycerol is ($C_3H_5(OH)_3$). The triglyceryl stearate is expressed $C_3H_5(O.C_{18}H_{35}O)_3$. The triglyceryl oleate is expressed $C_3H_5(O.C_{18}H_{33}O)_3$. The triglyceryl palmitate is expressed $C_3H_5(O.C_{16}H_{31}O)_3$.*

Strictly speaking, there is no distinct difference between a fat and an oil. Both are mixtures, as previously described, of various fatty acids, combined with glycerin, to form what the chemist calls glycerids. The combination of glycerids, which happen to be liquid at ordinary temperatures, are termed "*oils,*" and those which are solid at normal temperatures are known as "*fats.*" Most of the so-called oils are obtained from the fruits or seeds of plants; as, for instance, peanut, olive and cottonseed oils, although not all of the vegetable glycerids are oils, some being solid fats, or "butters," as cocoa butter, the fat contained in chocolate, nutmeg butter obtained from the nutmeg, and palm kernel and cocoanut oils, which, while liquid in warm climates, are fairly solid in temperate climates. Animals, generally speaking, produce fats which are hard at ordinary temperatures; as, for example, suet and lard. However, a few exceptions to this general statement are lard oil, bone oil, fish and whale oils, which are not solid at normal temperatures.

Nearly all fats and oils contain some glycerids, which solidify more rapidly than the other components. These are called stearin, while the more liquid portion is known as olein.

Stearin and palmitin chiefly occur in the solid fats and olein in the fluid oils. Such oils as tallow, neatsfoot, lard and olive oils have olein as the main constituent.

When a fat cools slowly, the stearin component separates as a fine, whitish precipitate and settles out. The process of cooling oils until part of the stearin crystallizes out and then filtering is called "wintering" the oil. To secure a fat with a high melting-point, tallow is subjected to a similar process, and it is then called "graining," and the hard oleostearin thus obtained is used in making lard substitutes, while the liquid or semi-solid oleo oil goes into oleomargarine.

When a fat or an oil decomposes, some of the glycerids break up, liberating fatty acids, which are partially responsible for the characteristic "burning" taste of rancid oils. Aldehydes and probably other compounds occur in rancid oils, and to these, more than to the fatty acids, are due the disagreeable odor and flavor of rancid oils.

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* NOTE. The triglyceryl linolate (Linolin) is expressed $C_3H_5\ (O.C_{18}H_{31}O)$ Linolin is a principal constituent of Linseed oil and other drying oils.

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FATTY OILS, USES AND CHARACTERISTICS.—Fats may cause spontaneous combustion. They hydrolize with water and free acids, which will pit metal surfaces and form soap. Due to their tendency to gum, they may clog bearings.

When a fatty oil is blended with a mineral oil, the above objections are largely eliminated, provided the percentage of fatty oil is not too high.

Some investigators have found that the fatty oil, when compounded with a mineral oil, aids in creating a more stable lubricating film and one that will adhere more closely than would a straight mineral oil film to the rubbing surfaces.

Fatty oils compounded with mineral oil should never be used for bearing lubrication where the temperature is high, because such oils tend to decompose. Except for special conditions, such as marine engines, hydraulic systems, etc., compounded oils should not be used, because they will emulsify readily.* They will not filter satisfactorily. For marine engines it has been found that a straight, heavy paraffin oil will do as good work as a compounded oil.

† All fatty oils and fats contain more or less fatty acids in a free form. An excess of this fatty acid is very undesirable from the standpoint of lubrication. The fatty acids belong to a group of organic compounds and must not be confused with inorganic acids, such as hydrochloric, sulphuric, etc.

The fatty acid may be freed from the fat, due to its becoming rancid, owing to oxidation, poor refining, heating with mineral acids or mucilaginous matter.

The most common fatty acids are stearic and oleic.

Stearic acid and oleic acid have a corrosive action on many metals. Note: See other references.

Animal oils or fats are secured from the cells of the adipose tissue of sheep, hogs, cows, etc.

Marine fats are obtained from the blubber of marine animals and from fish.

Vegetable fats are secured from the seeds and fruits of plants and trees.

Few fatty oils have a flashing-point below 300° F. Usually the flashing-point is from 450° to 500° F. Some oils have flash-points up to 600° F.

SOME COMMON USES FOR FATTY OILS.—Fatty oils are used in the following types of commercial oils :

"*Textile oils*": Olive, sperm, and lard oils are compounded with a light neutral petroleum oil. Peanut oil is also used; also red oil.

"*Marine oils*": Blown vegetable oils, such as rapeseed or cottonseed, are compounded with a heavy paraffin oil. The tendency of the blown vegetable oil is to cause the lubricant to form a lather and prevent its being washed from engine slides and bearings, due to the moisture, which is usually present at these points, and to give good viscosity to the lubricant.

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* NOTE. See index for reclamation of compounded oil.

† NOTE. See index for "germ process" and fatty acids.

"Wool oils": Stainless oils, spindle oils and wool oils are compounded with lard, De Gras, olive, neatsfoot or elaine, which are mixed with paraffin or neutral petroleum oils for these purposes. The compounded oils must be easily saponifiable, as they must often be removed from the fabric or yarn after worked up by the use of alkali and water. The percentage of compound usually runs from 15 to 20 per cent. in these oils, but sometimes may be as high as 60 per cent.

"Leather oils": Apron dressings, cordage oils and some wool oils which must be incorporated into the fabric or leather, either as a filler or to make the finished product pliable. As compounds for these oils and products, lard, olive and fish oils or De Gras are blended with a light petroleum oil for these purposes.

"Quenching oils": Mineral oils compounded with fish or lard oils are often used for this purpose.

"Signal and lamp oils": Cottonseed, lard, olive or sperm oils are compounded in percentages ranging from 20 to 60 per cent. with very light petroleum oils for this purpose. The fat in these compounds retards the oil flow in the wick, and gives a fat, bat-wing flame, instead of a long smoky one.

"Lubricants": The animal oils and fats most commonly used in lubrication are: Horse, tallow, lard, sperm, porpoise jaw, whale, etc. Vegetable oils used in lubrication are: Rape, castor, cottonseed, olive, palm oil, etc.

"Soaps": Olive, palm, peanut, castor, cottonseed, corn, soya bean, linseed, cocoanut elaine or red oil and fats are used.

OTHER GENERAL USES.—Mixing of paints, varnishes, waterproofing and like compounds, also as an important part of the food supply.

THE IMPORTANCE OF OILS AND FATS.—Fats and oils are a necessary part of our food supply.

They occupy an important place in the manufacture of certain munitions. One of the component parts of nitroglycerin is glycerin, obtained as a by-product in the manufacture of soap from certain oils and fats. It is considered that 10 tons of fat are required to yield 1 ton of glycerin, and that but 1 part of glycerin to every 9 parts of fatty acids, or soap, is produced from these oils and fats. The importance of a nation being self-sustaining in its requirements of fats and oils was demonstrated by the position Germany found herself in at the outbreak of the Great War. Germany developed such crops as potatoes, grains and sugar beets, but neglected to make herself self-sustaining in providing an adequate supply of fats and oils for food and technical needs. Thus she was forced to depend almost entirely upon other nations for the important vegetable fats and oils. When the war cut off these outside supplies, the Germans were forced to depend upon animal fats and oils. While this source might have provided sufficient oils for food and the production of glycerin, the lack of feed for the maintenance of herds of swine, cattle and sheep made it necessary to kill large quantities of hogs and other animals. The lack of concentrates from the oil mills was particularly felt in this respect, to supplement the potatoes, hay and grain feed for the stock. This shortage of oils and fats was a source of vital embarrassment for Germany.

SAPONIFICATION, FATTY OILS.—These oils are compounds of three elements: hydrogen (*H*), oxygen (*O*) and carbon (*C*), the proportions varying for different oils. Thus for linseed oil it is composed of approximately carbon, 77.44 per cent.; hydrogen, 11.10 per cent., and oxygen, 11.50 per cent.

When these oils are boiled with caustic potash, lime or caustic soda they are decomposed. Two bodies are formed, one is called glycerol and the other is called soap.

Saponification may also be effected by heating with water under pressure or by heating with sulphuric acid.

All oils which can be transferred into soap by saponification are called "saponifiable oils."

The action of caustic soda or of caustic potash, which are called alkalies, upon a typical fatty body is as follows:

$$\underbrace{C_3H_5(C_{18}H_{35}O_2)_3}_{\substack{\text{Glyceryl stearate}\\ \text{stearin}}} + \underbrace{3NaOH}_{\text{Caustic soda}} = \underbrace{3NaC_{18}H_{35}O_2}_{\substack{\text{Sodium stearate}\\ \text{soap}}} + \underbrace{C_3H_5(OH)_3}_{\text{Glycerin}}$$

Stearin is the principal constituent of such animal fats as tallow.

$$\underbrace{C_3H_5(C_{18}H_{33}O_2)_3}_{\substack{\text{Glyceryl oleate}\\ \text{olein}}} + \underbrace{3NaOH}_{\substack{\text{Caustic}\\ \text{soda}}} = \underbrace{3NaC_{18}H_{33}O_2}_{\substack{\text{Sodium oleate}\\ \text{soap}}} + \underbrace{C_3H_5(OH)_3}_{\text{Glycerin}}$$

Olein is the chief constituent of olive oil and the fluid oils of vegetable source.

$$\underbrace{C_3H_5(C_{18}H_{31}O_2)_3}_{\substack{\text{Glyceryl linolate}\\ \text{linolin}}} + \underbrace{3KOH}_{\substack{\text{Caustic}\\ \text{potash}}} = \underbrace{3KC_{18}H_{31}O_2}_{\substack{\text{Potassium}\\ \text{linolate soap}}} + \underbrace{C_3H_5(OH)_3}_{\text{Glycerin}}$$

Linolin is the principal constituent of linseed oil and drying oils.

In the above formulæ, the symbols stand for the following elements:

Symbol	Element	Atomic weight
C =	Carbon =	12
O =	Oxygen =	16
H =	Hydrogen =	1
Ca =	Calcium =	40
Na =	Sodium =	23
K =	Potassium =	39

Soaps which are obtained with the use of soda or of potash are soluble in water, but if made with lime they are not soluble.

THE SAPONIFICATION VALUE.—(Test methods, U. S. Division Military Aeronautics, acknowledgment to A. S. T. M.) The saponification value of an oil fat or wax or a compound of these with mineral oils is the number of parts per 100 of caustic potash required to saponify the mixed esters contained in such fats or compounds.

For the determination of this value the following reagents are required:

Approximately semi-normal alcoholic potash, made by dissolving about 18 grams of the purest obtainable potash in 500 c.c. of pure rectified alcohol. As potash "pure by alcohol" usually contains about 20 per cent. of water, this solution will be about semi-normal in strength; if anhydrous potash be used, 14 grams would be enough.

Semi-normal hydrochloric acid accurately standardized with pure sodium carbonate, which has been heated to just below redness for five minutes and cooled in a platinum crucible in a desiccator immediately before weighing.

Phenolphthalein solution containing 3 grams dissolved in 100 c.c. of alcohol, neutralized by shaking with dry precipitated calcium carbonate and filtering.

METHOD

For determination of saponification value: Accurately weigh 2.5 grams of the oil or fat to be tested into a small wide-necked flask, and add 25 c.c. of the semi-normal potash solution from a pipette. Close flask with a perforated cork in which is inserted a glass tube 18 inches long, to act as a reflux condenser. Boil on water bath, occasionally removing and agitating with a rotary motion to facilitate saponification, being careful not to splash any of the contents on the cork. Compounds of fixed and mineral oils, especially when the proportion of mineral oil is large, require boiling for an hour or more to complete saponification of the fixed oil. Prepare a control test, by measuring into a flask of the same size and shape 25 c.c. of the same semi-normal potash solution and boil it 15 minutes, using cork and tube as reflex condenser. Remove cork from the blank, add about 1 c.c. of the phenolphthalein solution and carefully titrate with the semi-normal acid until the crimson color is just bleached; the flask containing the saponified oil is then similarly treated, and from the relative volumes of acid used the saponification value is calculated, as shown by the following example:

Weight of oil taken	2.5 grams
Volume of $\frac{N}{2}$ acid used for the blank	26.05 c.c.
Volume of $\frac{N}{2}$ acid used for the analysis	10.55 c.c.
Difference equals $\frac{N}{2}$ KOH required for saponification	15.50 c.c.

Therefore, 100 grams of oil required $15.50 \times 0.02807 \times 40 = 17.40$ grams caustic potash for complete saponification; *i. e.*, the saponification value is 17.40 parts per hundred.

INTERFACIAL TENSION (SURFACE TENSION BETWEEN OIL AND WATER).—Messrs. Wells and Southcombe, *Journal Society of Chemical Industry*, 1920, pp. 51–60 T, state as follows: "In an investigation to determine a criterion of 'oiliness,' the surface tension between oils and water was measured. * * * The method used for the experiment was as follows: A pipette, as shown (Fig. 1, Sec. 5), consisting of a U-shaped capillary tube provided with a bulb *A* and a ground glass orifice *B*. The bulb *A* is filled with oil to the mark *E*. By means of the capillary *D* a very

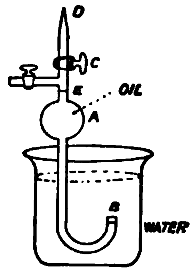

FIG. 1. SEC. 5.—Pipette for measuring interfacial tension.

slow flow of oil may be obtained at *B* by opening the stop cock *C*. The orifice is immersed in a beaker of water and the number of drops formed in a given volume of oil in *A* is counted. The surface tension oil-water is inversely proportional to the number of drops (Donnan, *Zeit. f. Physik. Chem.*, vol. 31, etc.). A series of mineral oils were tested with this instrument and then a series of animal and vegetable oils and compounded oils. The following table shows a few of the results selected from a very large number of trials:

Table of Interfacial Tension by Drop Numbers of Various Oils Against Water

Oil.	Mean temperature 70° F. No. of drops at constant orifice and head.	Tension in arbitrary units.	
Paraffinum liquidum	95	100	Mineral oils
0.905 mineral	101	94	
Solar red mineral	102	95	
Non-viscous neutral	99	93	
Olive	132	72	Fatty oils
Rape	138	68	
Cocoanut	161	59	
Lard oil	128	73	

" * * * The interfacial tension against water of the vegetable and animal oils is much lower than in the case of the mineral oil. * * * After considerable experimentation, the experimenters proved that the lowering of interfacial tension against water in the case of fatty oils was due to their slight content of free fatty acidity. The following table shows some of the results Messrs. Wells and Southcombe obtained:

Oil.	Free fatty acids, calc. as oleic.	Drop no.	Interfacial tension.
0.905 mineral	nil	101	100
98 per cent. mineral; 2 per cent. com. fatty acids	1.9	125	80
97 per cent. mineral; 3 per cent. com. fatty acids	2.8	130	78
Olive	2.2	125	80
Olive	4.5	140	72
Rape	2.5	132	76
Cocoanut	4.1	148	68
Olive (neutral)	0.1	110	92
Rape (neutral)	0.15	108	93

"By removing the free fatty acids from saponifiable oils the tension rises and by adding free fatty acids to mineral oils the tension can be lowered." * * The authors state that with reference to the influence of these results upon the theory and practice of lubrication of solid surfaces, it may be argued that the interface between oil and water is a different thing from the interface between oil and metal. However, they point out that the similarity is not unknown in other instances, and to obtain conclusive evidence, * * * "Professor Lewis has measured the interfacial tension between oil and a liquid metal—mercury. * * * His results are as follows: Pure neutral mineral oil, 100; same mineral oil plus 2 per cent. of commercial fatty acid, 89. It is seen here again that there is a lowering in the interfacial tension as a result of the addition of the organic acids, and what is more striking, the relative lowering produced is very much the same as it is in the case of an oil-water interface."

IODINE VALUE.—By iodine value is meant the number of grams of iodine which are absorbed by 100 grams of a fat under definite conditions, viz.: Time of contact, nature iodine, carrier, excess of iodine, etc. In other words, the percentage of iodine.

Holde and Muller state: "The iodine value is important in the testing of purity of a fat. According to the size of the iodine value the fats are divided into '*drying oils*,' with iodine values from 130–200 (linseed oil, wood oil, poppy-seed oil); '*semi-drying*' oils, with iodine values ranging from 95–130 (corn oil, rape oil, cottonseed oil, sesame oil), and '*non-drying*' oils, with iodine values under 95 (olive oil, peanut oil and castor oil). The iodine values of fats of land animals are under 80, those of marine animals generally over 100."

The iodine value may also be described as the percentage of iodine that will be absorbed by an oil. For lard, tallow, etc., it is lower than the iodine value of vegetable or fish oils. Fatty oils are called "fixed oils," because they are obtained from fats and are a fatty acid combined with an alcohol, not readily distillable. Chemically speaking, they are neutral glycerides of fatty acids.

For description of methods of determining the iodine value, see "Oil Analysis," p. 59, by Augustus H. Gill. There are two methods, viz.: Hanus and Hubl.

NOTE. Also see index for other information on Iodine Value.

BLOWN OILS

These oils are prepared by blowing air through the oil, which has first been heated to about 70° or slightly until the desired gravity is attained. The oils generally blown are rapeseed, cottonseed, ravison, fish and whale oil. After the action has started the outside heating is stopped. Blown oils have a characteristic odor, which is unpleasant.

Blown cottonseed and blown rape oils are very similar, with the exception of the cold test of the fatty acids, the rape oil having the lower cold test.

The iodine number of blown oils is lower than that of the unblown oils. Two samples of oils tested gave the following:

	Iodine value
Refined rape oil	102.00
Blown rape oil	61.1
Summer yellow cottonseed	108
Blown cottonseed	76.6

The flashing points of oils are lowered by blowing. Blown cottonseed is somewhat turbid as a rule, and tends to deposit a sediment after standing.

Blown oils are very often used in mixtures with mineral oil for special forms of lubricating oils, such as marine engine oil. A peculiarity of blown oils is their property of only making a staple mixture with petroleum lubricating oil when mixed with certain proportions. For instance, usually about 20 to 30 per cent. of blown oils will give a clear mixture in combination with paraffin mineral oils, but a smaller percentage of the blown oil will usually result in the mixture settling in layers after standing in a cool place. The percentages of the blown and mineral oils that will give a staple mixture is also dependent upon the gravities and source of the petroleum oils. Some authorities have stated that the blown oil is the solvent and not the mineral oil. Very often mixtures of blown and mineral oils will remain clear while kept in a warm place, but will separate when put in a cool place. These factors are important in considering an oil for marine use, particularly with wick feeds.

Samples of blown rape, whale, ravison and cottonseed oils gave the following tests:

Characteristic Tests of Blown Oils of Various Kinds

Test	Rape oil East Indian	Whale oil	Cottonseed oil	Ravison oil
Baumé gravity	(13.5 to 15.4)	(14 to 15)	(14.5 to 15)	(14.4 to 15)
Iodine value	(52 to 70)	(55 to 63)	56.1 to 60	66.0
Saponification number	188 to 214	210 to 214	214 to 225	214 to 229
Viscosity (Saybolt) at 212° F. (approx.)	225	180	215	335

The gravity and viscosity of blown oils are determined by the length of blowing time. Fish oil is usually blown to 10° B. gravity, which gives

a viscosity of about 325 Saybolt at 212° F. Rape is usually blown to 14° B. gravity, which gives a viscosity of about 300 Saybolt at 212° F.

As an illustration of the effect of blowing upon the viscosity and gravity of peanut oil, the following values taken from a sample of blown peanut oil are given:

BLOWING PEANUT OIL

Gravity Baumé	Viscosity at 212° F. Saybolt
22.7	60
22.53	60
20.04	71
19.9	81
18.9	86

Practically no effect upon its solubility in gasoline was shown after the oil was blown as compared with the oil before blowing.

MIXING BLOWN OILS AND MINERAL OILS.—Gray states that a better mixture can be obtained when mixing blown oils and mineral oils to make marine engine oils if the blown oil is first mixed with a light-bodied paraffin oil, and then this mixture worked into the mineral lubricating oil which is desired as the mineral base.

Experiments made at one plant indicated that great trouble will be had in getting a mixture that will stay clear if a cylinder stock is used to give more viscosity to the mineral component of a mixture of mineral lubricating oil and blown oils.

SULPHONATED OILS

Until recently castor oil was practically the only oil that was sulphonated, but now there are several other oils used for that purpose.

A sulphonated oil is a fatty oil that has been treated with sulphuric acid, the excess acid being washed out and only that which is combined organically with the glyceride permitted to remain therein. After this operation the oil is neutralized with an alkali, either soda or ammonia or a combination, and an oil of this nature when properly sulphonated should give a solution in water having a slight opalescence.

Turkey-red oil used in connection with printing Turkey and alizarine reds on cotton, and in printing various colors with such mordant dyes as alizarine yellows, chrome yellow, etc., to give a fuller, faster color, is a sulphated castor oil. It is made and sold under many trade names. (See index.)

Also bases for soluble metal cutting and milling oils are prepared by sulphating.

SPONTANEOUS COMBUSTION

DEFINITION AND CAUSES.—There are three groups of fatty oils; namely, "drying," such as linseed, which when exposed in thin films become hard; next there are the semi-drying oils, and then there are the non-drying oils, such as sperm, olive and lard oils, which will remain soft when exposed to the air. Drying is allied to the absorption of oxygen, and the absorption of oxygen develops heat, the greater the absorption the greater the heat developed. Since the petroleum oils do not absorb oxygen, they are a check-up on the heat development when they are compounded with fatty oils, which do absorb oxygen.

When these heat-developing oils are mixed with cotton or wool fibres, the heat produced may rise so high that there will be spontaneous combustion produced, and the mass may burst into flame.

Various scientific investigators have found that the spontaneous combustion of oiled wool or cotton is dependent upon several factors: (*a*) The "*proportion of the content of oil* to the mass of *wool or cotton*"; that is, if too high a percentage or too low a percentage of the oil is present, spontaneous combustion will not occur. (*b*) The "*presence of moisture*" also affects spontaneous combustion, and reports indicate that small percentages of moisture tend to aid the action, due to the fact that the water carries oxygen to the oil and aids in its oxidation. (*c*) The "*kind of oil used*" determines whether oxidation will occur rapidly or slowly, and the liability is proportionally increased or decreased. (*d*) The "*flash-point*" of the oils has some effect upon the spread of the resulting fire when it has been started. Oils such as olive, cottonseed, neatsfoot and lard oils usually have flashing-points that are well above 450° F., so that they are safe oils from that standpoint.

FREE FATTY ACID AND ITS EFFECT.—Mackey, as stated in the *Journ. Soc. Chem. Ind.*, xiii, 1894, p. 1164, found that in experiments with olive and cottonseed oils, the free acids prepared from these oils have a tendency to develop heat and to fire cotton that is greater than is the case with the neutral oils themselves. He considers that this is an important feature, in that in woolen mills the recovered cloth oils and distilled oleines consist largely of free fatty acids.

DRYING TESTS OF SOME OILS ON HEATING.—The following tests were made to determine the relative drying qualities of certain drying oils and other products when dried in an air bath at various temperatures and for different lengths of time: *

Products	Weight, percentage of original, after 24 hours at 212° F. air current	Weight, percentage of original, after 1 hour at 400° F. in large oven	Percentage of weight when remainder was heated in air to dryness
China wood oil	102.2	98.77	0.04
Corn oil	100.74	95.40	0.40
Cottonseed oil	100.65	96.00	0.09
Soya bean oil	100.95	95.45	0.68
Fish oil (light pressed)	100.50	92.65	1.25
Raw linseed	100.20	97.00	0.20
Boiled linseed	93.50	90.41	0.50
Resin oil (first run)	63.40	10.42	0.05
Tar oil (heavy)	67.20	38.30	0.08
Tar oil (crude)	51.80	34.30	0.08
Tar oil (light)	31.20	11.60	0.09
Paraffin (mineral oil)	72.00	33.00	0.14

DRYING TESTS.—When the following oils were exposed to the air at normal temperatures on glass slides in thin films, the following percentages of loss in weight were noted:

Oil	24 hours	48 hours	72 hours
	per cent	*per cent*	*per cent*
China wood oil	10.71	12.64	15.93
Grape oil	10.37	13.30	17.02
Soya bean oil	4.42	9.89	13.80
Linseed oil (A)	15.19	17.68	24.86
Perilla oil	20.49	21.31	21.85

MACKAY'S CLOTH OIL TESTER.—This instrument consists of a cylindrical copper water bath, tinned on the inside. It is 4 inches in diameter and 7 inches high, internally measured. It is provided with a lid, that has a short central tube for the thermometer and two tubes *N* and *B* for air circulation. There is a gauze cylinder *C*, which is used to hold the oiled wool. This instrument is intended to provide a quick method for testing the liability of oils to develop spontaneous heat under the conditions found in textile mills. In testing, the oil is weighed into a shallow dish containing pure cotton wool, and after the oil has been thoroughly taken up by the wool it is packed in the gauze cylinder, and a thermometer is held upright in the wool while the wool is packed around it. The water in the jacket is then heated and the wool cylinder placed into the inner

* NOTE. The samples were dried in porcelain crucibles, and the weights obtained after each period, as indicated.

chamber, the lid is put on, and the water in the jacket is kept steadily boiling. The temperature of the wool is taken at regular intervals by means of the thermometer. Mackay states that if an oil, when tested as above described, reaches a temperature of 200° C. in two hours, it is not suitable for use in a mill, because of the fire risk. Safe oils, such as

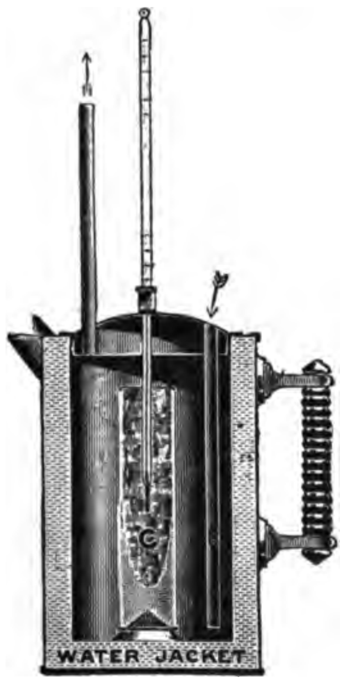

FIG. 2. SEC. 5.—Mackay's cloth oil tester. (Courtesy Eimer & Amend.)

pure olive oil, will not cause the wool to rise much higher than the boiling-point of the water (100° C. or 212° F.). This temperature is reached usually after about one hour, and the temperature thereafter remains about constant. With an oil like cottonseed, the temperature will rise to about 200° C. in about an hour and a half.

See Fig. 2, Sec. 5, for cut of Mackay's Cloth Oil Tester.

TRADING UNITS

Name	Trading unit
Cod oil	Gallon.
Menhaden oil	Gallon.
Porpoise oil	Gallon.
Seal oil	Gallon.
Sperm oil	Gallon.
Whale oil	Gallon.
De Gras	Pound.
Horse fat	Pound.
Lard oil	Gallon.
Neatsfoot	Gallon.
Sod oil	Gallon.
Tallow oil	Gallon.
China wood oil	Pound.
Cocoanut oil	Pound.
Corn oil	Pound.
Cottonseed (crude)	Pound.
Linseed oil	Gallon.
Olive oil	Gallon.
Palm oil	Pound.
Palm kernel	Pound.
Peanut oil (crude at mill)	Gallon.
Peanut oil (edible or Oriental)	Pound.
Rapeseed oil	Gallon.
Soya bean	Pound.
Castor oil	Pound.

FISH AND MARINE ANIMAL OILS

FISH OILS.—These oils are obtained by boiling fish in large vats. The oil which boils out is skimmed off. It has a light-brown color, a low percentage of free fatty acid and a pronounced fishy odor. The oil is derived from menhadens, which are somewhat larger than herring. The fish are placed in pans treated with steam, which digests the flesh, so that after standing for a time the oil rises to the surface of the water and can be skimmed off. The color depends upon the freshness of the fish and the length of boiling time. Dark oil is from putrified fish. The crude oils range from yellow to brown, but are bleached to a pure white if desired.

Commercial grades are known as: Gurry Oil, Dark Pressed, Light Pressed or Winter Pressed, and Bleached.

Fish oil may be blown.

The light pressed or winter pressed grade is used to some extent by varnish and paint manufacturers to replace linseed oil. The film it produces on drying is not as close lying or adherent to the surface covered as the film formed with linseed oil, however.

U. S. Navy Specifications for Fish Oil (5206) (Aug. 1, 1914)

QUALITY

1. To be strictly pure winter-strained, bleached, air-blown menhaden fish oil, free from adulteration of any kind.

CHEMICAL CONSTANTS

2. The oil shall show upon examination:

	Maximum	Minimum
Specific gravity	0.935	0.930
Iodine number (Hanus)	165	145
Acid number	6	.....

PHYSICAL CHARACTERISTICS

3. The oil when poured on a glass plate and allowed to drain and dry in a vertical position, guarded from dust and exposure to weather, shall be practically free from tack in less than 75 hours at a temperature of 70° F. When chilled, the oil shall flow at temperatures as low as 32° F.

BASIS OF PURCHASE

4. To be purchased by the commercial gallon; to be inspected by weight and number of gallons to be determined at the rate of 7½ gallons of oil per gallon.

SEAL OILS.—They have a strong odor, a low free fatty acid percentage and a high flashing-point. They vary according to color. Specific gravity about 0.926.

SPERM OIL.—This oil is extracted from the head cavity of the sperm whale. During life the contents of the cavity are in a fluid condition. As soon as the head matter is removed from the cavity, white crystalline flakes of wax. known as spermaceti, separate out. They have a

fishy odor. This leaves a clear yellow fluid. Sperm oil is the lightest and most fluid of the fixed oils. Inferior grades are obtained from sperm-whale blubber. Sperm oil is extracted on shipboard. Crude is delivered to refineries. It is placed in tanks and chilled at 32° F. and allowed to stand several weeks, to freeze out the spermaceti. Semi-solid mass is placed in bags and pressed, producing winter sperm. The material left in the bags is warmed to 50° F. and pressed, giving "Spring Sperm Oil." A third kind, known as "Pressed Sperm Oil," is obtained by further pressing at a higher temperature. Sperm oil is classed by some authorities as a liquid wax. Its viscosity varies comparatively less than other oils in heating. (See curves.)

U. S. Navy Specifications for Sperm Oil (14-0-7a) (Oct. 2, 1916)

GENERAL SPECIFICATIONS

1. General Specifications for Inspection of Material, issued by the Navy Department, in effect at date of opening bids, shall form part of these specifications.

COMPOSITION

2. Must be of pure winter-strained bleached sperm oil, free from mixture or adulteration with animal, mineral, vegetable, or other fish oil, grease, lard, or tallow, or any other adulterant.

SPECIFIC GRAVITY—FLASH—ACIDITY

3. The specific gravity must be between 0.875 and 0.885. The flash test of the oil in open cup must not be under 440° F. The oil must show less acidity specifically than the equivalent of 0.25 per cent. of oleic acid. To be purchased and inspected by weight; the number of pounds per gallon to be determined by the specific gravity of the oil at 60° F. multiplied by 8.33 pounds, the weight of a gallon (231 cubic inches) of distilled water at the same temperature.

SAMPLING

4. Before acceptance the oil will be inspected. Samples of each lot will be taken at random, the samples well mixed together in a clean vessel, and sample for test taken from this mixture. Should the mixture be found to contain any impurities or adulterations, the whole delivery of oil it represents will be rejected, and is to be removed by the contractor at his own expense.

WHALE OIL.—The best grade is known as "Train Oil." It is extracted from the blubber of Arctic or Greenland whales. The blubber of a large whale may yield 7500 gallons of oil, while a small whale may only yield 50 to 100 gallons of oil. The best grades are from the first boiling, after which the blubber is subjected to a second treatment, yielding an inferior oil, known as No. 0 and No. 1. A third grade is made from the residual blubber and flesh of the whale. Even the best grades have strong drying qualities.

It is brownish yellow and has a bad smell and a nutty taste.

SPECIFICATIONS FOR WHALE OIL.—The Navy Department specifications call for: The best grade of winter bleached whale oil, free from adulteration. Tested with litmus paper, the oil shall show no trace of acid. It should not become torpid at from 32° to 42° Fahr., nor cease to flow at from 17° to 18° Fahr., and shall not flash at less than 490° Fahr. Specific gravity at 60° Fahr. shall be from 0.921 to 0.927. The oil is purchased by liquid measure (gallons), but inspected by weight. (Grav. at 60° Fahr. x 8.33.)

SPECIFICATIONS FOR WHALE OIL SUBSTITUTE.—The following specifications were used by the Navy Department for a whale-oil substitute: The oil shall be made from fish oil, best grade, winter bleached, and whale oil. It shall contain no mineral oil. Tests as follows:

(*a*) Litmus test to show no acid.
(*b*) Not to be torpid at 30° to 35° Fahr..
(*c*) Not to cease to flow at from 18° Fahr.
(*d*) Flash not less than 460°–490° Fahr.
(*e*) Specific gravity at 60° F. 0.920 to 0.922.

VEGETABLE AND SEED OILS

Generally, vegetable oils are obtained by pressing them from seeds or fruit, by means of heavy hydraulic presses or continuous expellers. They may also be extracted by means of volatile solvents, such as carbon-bisulphide or gasoline.

In the case of fruits, like the olive, which give up their oils easily, "cold pressing" is used after the fruit has been properly ground. In the case of the usual oil seeds, however, little oil is yielded by cold pressing, and they are cooked, and then "pressed hot." Generally speaking, cold-pressed oils do not require any further treatment to make them edible, and such oils are known as "virgin oils." "Hot pressed" and "extracted" oils contain coloring matter and flavoring matter, which must be removed by refining operations before the oils are suitable for food, and in many cases for technical or industrial purposes.

Refining consists, in this case, of treatment of the oil to remove the undesirable flavors and coloring substances. Several acids and alkalies may be used for this purpose, and also a number of salts, such as borax, potassium bichromate, water glass and potassium permanganate. The usual method, commercially used, is to treat the warm oil with a caustic-soda solution, thus neutralizing the free fatty acids, which may be present and destroying or precipitating much of the coloring matter. The alkali combines with the free acids and some of the oil to form a soap. This soap settles to the bottom of the refining kettle, and in the United States is termed "soap stock" or "foots," and is used by soap manufacturers.

Many oils are also bleached, by mixing the hot refined oil with a small quantity of Fuller's earth, which takes up a large part of the remaining color that was not removed by the caustic soda or other alkali. The Fuller's earth and its absorbed coloring matter are then filtered out of the oil by forcing the mixture through a filter press.

"*Deodorizing*" is a process used for making some oils, such as those used in lard substitutes, where a very bland oil having little odor and flavor is desired. This process consists in blowing superheated steam through the oil, which is heated in a vacuum kettle. Hydrogen has lately been substituted for the steam, and it is now practicable to deodorize even fish oils.

"*Hydrogenation*" is a process for converting liquid oils into solid fats. In this process reduced nickel is used to effect a combination of hydrogen gas and the liquid glycerids. The hydrogen unites with the olein components of the oil and changes them to stearins, which, as has been previously described, are solid at normal temperatures. The nickel does not combine with the oil, at least, not permanently, and can be removed by filtration at the end of the process and used again. A substance that acts as described in the case of the nickel, to collect one chemical substance and pass it along and force its acceptance on another substance, is termed a "catalyst."

This process also makes it possible to convert oils formerly considered inedible into sweet products. It is said that in some parts of the world whale oil and some fish oils are now being refined, deodorized and hardened, and that a lard substitute is said to be produced from fresh herring oil by this process.

CASTOR OIL.—This oil is a semi-drying oil, but will thicken on long standing and when used as a lubricant quickly thins out in service.

An idea of the effect of temperature on the viscosity of chemically pure castor oil may be obtained from the following figures, which were taken with an average sample:

At 100° Fahr.	Vis. Say.	1200 Secs.
At 125° Fahr.	Vis. Say.	600 Secs.
At 150° Fahr.	Vis. Say.	300 Secs.
At 175° Fahr.	Vis. Say.	175 Secs.
At 200° Fahr.	Vis. Say.	110 Secs.
At 250° Fahr.	Vis. Say.	60 Secs.
At 300° Fahr.	Vis. Say.	40 Secs.

Castor oil is obtained from the seeds of the castor-oil plant, originally a native of India. The odor and color vary, the best grades being practically colorless and odorless and the lower grades being greenish and having a nauseating smell. Castor oil contains the glycerid of a peculiar acid, known as ricinoleic acid, which is distinctive to this oil.

The press cake from castor beans contains a dangerous poisonous principle, which makes it unsuitable as cattle feed. It has value, however, as a fertilizer. The hydraulic press is used to crush the beans in America, while abroad the volatile solvent method is widely used.

No. 3 Castor Oil.—Tests of: A sample of No. 3 Castor Oil tested:

Color: Greenish.
Gravity: 15 B.
Flash: 485° Fahr.
Fire: 550° Fahr.
Free fatty acid: 3.10 for one sample.
Free fatty acid: 3.21 for one sample.
Free fatty acid: 3.77 for one sample.
Cold test: 0° Fahr.
Iodine value: 92.3.
Viscosity at 212° Fahr.: 160 Saybolt.

First Quality Castor.—Tests of: A sample of First Quality Castor tested as follows:

Gravity: 15 B.
Viscosity at 212° Fahr.: 110 Saybolt.
Flash: 545° Fahr.
Fire: 600° Fahr.
Free fatty acid: 0.57.
Cold test: 0° Fahr.

A sample of First Quality Castor Oil (Baker's A A) tested:

Gravity: 15 B.
Viscosity at 212° Fahr.: 100 Saybolt.
Free fatty acid: .53 for one sample.
Free fatty acid: .36 for another sample.

Saponification: 185.
Cold test: 0° Fahr. minus.
Iodine value: 0.83 and 0.86.

(B)

Another test of First Quality Castor Oil showed:

Gravity: 15.33.
Acid number: 1.03.
Flash: 475° Fahr.
Viscosity at 100: 1375 Saybolt.
Viscosity at 212: 110 Saybolt.
Viscosity at 300: 60 Saybolt.
Conradson carbon: 0.18.
Colorless.

Castor Oil and Mineral Oil.—When Solar Red and A A Castor were mixed, using Refined Rape Oil as a vehicle, the following proportions were found to give a mixture which showed no separation on standing:

10 per cent. Castor (A A).
40 per cent. Refined Rape.
50 per cent. Solar Red.

The Solar Red Mineral Oil had these tests:

(22.2 Gravity (Baumé).
410 Flash.
35 Cold test.
295 Vis. Say. at 100° Fahr.).

When castor oil (A A) was mixed as follows with gasoline, the mixture showed these results:

Fifty per cent. of 60–62 gasoline and 50 per cent. castor oil, when mixed, showed that after considerable time was allowed for separation, about 40 per cent. of the gasoline separated out and the remaining 60 per cent. of the mixture was oil and gasoline. A clear separation was observed between the 40 and 60 per cent. mixtures.

When the sample of castor marked (B) above was tested for the quantity of gasoline it would take up, the following results were obtained: At 100° Fahr., using 62° gasoline and a 50–50 mix, the oil took up equal parts of the gasoline.

At ordinary temperatures castor oil is only slightly soluble in mineral oils, but castor oil is able to dissolve mineral spirit in proportions, depending upon the specific gravity of the mineral oil, decreasing as the specific gravity increases.

Notes on Castor Oil.—Lewkowitsch says:

"Properly refined castor oil keeps very well and does not easily turn rancid, as observations made in the author's laboratory have shown. A sample exposed to the atmosphere for four years contained only 1 per cent. of free fatty acids."

Another or possibly the same sample, which was exposed for four years, had its specific gravity at 60° F. (15.6 C.) increased from 0.9591 to 0.09629.

Castor oil is used as a lubricant, particularly in some types of airplane

engines, also for making soap, Turkey red oil, and other products, such as sticky flypaper, imitation leathers, etc.

Density and Viscosity of Castor Oil According to Deering and Redwood

Specific gravity at 60° F (15.6° C)	Density at 60° F	Time of discharge, in seconds, Redwood viscosimeter, at 100° F (37.8° C)	Kinematic viscosity at 100° F
0.9637 minimum	0.9628	1190 maximum	3.093
0.9639	.9630	1160 minimum	3.015
0.9642 maximum	.9638	1174	3.051

The kinematic viscosities were determined by Higgins's equation.

$$\frac{\mu}{\gamma} = 0.00260\,t - \frac{1.715}{t}.$$

Some experimenters claim that pure castor oil will mix with a mineral lubricating oil if a third oil, such as rape or lard oil, is used as a vehicle for the castor.

"*Miscible Castor Oil*" is obtained by heating the oil at about 560° F. until it loses about 5 to 6 per cent. of its weight. It will then mix with mineral oils.

CHINA WOOD OIL.—This oil contains its own driers and has the nature of an oil and a varnish gum. It dries readily. In a test, where a small sample was subjected to a temperature of 212° Fahr. in an air current, it gained 2.2 per cent. in weight due to oxidation, and finally gave a strong, tough film.

It is made from the "tung nut" and comes from China. It is also known as China Nut Oil. Tung oil is poisonous, or at least so strongly laxative that it cannot be used in foods, and there seems to be no method of refining it to obtain an edible oil. It is the best substitute for linseed oil in paints, and especially in varnish. When resin is used instead of foreign varnish gums, tung oil is said to be superior to linseed oil. Spar varnishes, which do not discolor when wet, are largely tung oil-resin preparations. It has also been used in waterproofing concrete ships.

COCOANUT OIL.—In Northern countries this oil is in the form of a white, soft fat. In Asiatic countries it is a water-white liquid. It is obtained from the cocoanut, which is the fruit of the coco tree. The outer portion of the nut is fibrous. Inside this is the nut, consisting of a hard outer layer, inside of which is a layer of pulp of white color and the central portion of the nut is filled with a milky fluid. The pulp is dried, and then is known as "coprah" (also "copra"). It is heated with water, and the oil which comes to the top is skimmed off. Inferior oil is made by softening the pulp with water and heat and pressing the oil out in an oil press.

The main kinds of cocoanut oil are Cochin, Ceylon, Malabar, Manila and Mauritius.

Cocoanut oil is largely used in soap-making; also in making butter substitutes. It is easily saponified.

Typical physical tests are:

Specific gravity at 60° F.: 0.930 to 0.959.
Specific gravity at 212° F.: .08736 to .874.
Solidifying point: 60 to 70° Fahr.
Melting point: 70 to 80° Fahr.
Saponification (Koettstorfer): 24.6 to 26.0 per cent. *KOH.*
Iodine value (Hubl): 8 to 9.3 per cent.

"Copra" contains a high percentage of oil (63 to 70 per cent.). Cocoanut oil contains glycerids of the lower fatty acids, which are more easily decomposed than those of other seed oils, and, therefore, greater care must be exercised in refining it to prevent high loss, due to conversion of the oil to soap. Refined cocoanut oil is used in the production of vegetable margarines, often called "nut margarines." In "butter substitutes" about 50 parts of cocoanut oil, 25 parts of peanut or other vegetable oil, and 25 parts of ripened milk are mixed by churning, and then quickly chilled in such a manner that the fat particles when collected and worked yield a smooth butter-like product.

In order to accomplish this, the batch may be sprayed into a large tank of cold water, or it may be run from the churn in the form of a thin sheet, under an ice-water spray. The batch, when congealed into fine waxy particles, is collected in trucks, and put in the tempering room, where it is kept to ripen and take on a butter flavor. When ripened, after a day or two, it is salted by the workers, and the excess moisture squeezed out. The product is then ready for shipping.

The by-products from refining cocoanut oil are used in making soaps.

Some manufacturers of the oil separate the low melting part of the oil from the high melting parts, the liquid portion being sold as cocoanut olein and used as a cooking oil, and the high melting stearin used as an adulterant for cocoa butter and as a filling for cookies and wafers, and also to enter into vegetable margarines.

CORN OIL.—This oil is used for food and for technical purposes. Corn oil is sometimes called "Maize Oil." It is obtained from the small germ portion of common Indian corn. In the preparation of cornstarch, hominy feed, brewers' grits and sometimes of cornmeal, the germ is more or less separated from the rest of the grain. In de-germinating the corn by the old process, the corn is soaked in dilute sulphurous acid for a period of time, and the germ, in which the oil is already rancid, is separated from the rest of the grain. In the new process, the germs are removed by mechanical means, without the addition of water, and this process is known as the "dry process."

The germs are cured until they get tough, and are then run through "flaking rolls," which flatten them and break down the oil cells, but do not grind the material. The general practice is then to run the germs from the flaking rolls into expellers, similar to cottonseed expellers.

The oil is refined before being used for food. Crude corn oil is used in various industrial products, and in making soap, paint and linoleum.

COTTONSEED OIL.—This oil is produced in numerous grades from the seeds of the cotton plant. The seeds are removed from the "boll" by the "ginning process," and are then crushed and the oil

expressed. Its color is usually deep yellow to dark-reddish yellow. It is often used to adulterate lard oil. It is largely used to produce miners' lamp oils in compound with petroleum oil. Specific gravity at 60° F., 0.922 to .928.

There are several commercial grades, as follows:

(*a*) Crude cottonseed oil.
(*b*) Summer yellow cottonseed oil.
(*c*) Summer white cottonseed oil.
(*d*) Winter white cottonseed.

According to the U. S. Department of Agriculture, the United States produces more cottonseed oil than any other single oil, and, likewise, consumes more of the oil than all the other vegetable oils combined.

It is not only used for technical and industrial purposes, but it is also used for both table and cooking purposes. It forms the bulk of lard substitutes, and large amounts are used in manufacturing oleomargarine, and also in the making of soaps.

The manufacture of American cottonseed oil is a typical "hot-press" process, and the machinery and processes used in the United States for the production of this oil are said to be superior to those in use in other countries. A description of the preparation for the press at a crude oil mill is as follows:

The cotton seed is first run through revolving screens to separate out the large pieces of refuse. It is then passed over shaking sieves and magnets, and then through cyclone cleaners to remove nails, sand, dirt and dust. Then the seeds are fed to the "delinters," where the short cotton hairs which the gins failed to take off are removed and condensed into a felt, which is rolled out like cotton batting and is used by the mattress maker or gun-cotton manufacturer.

From the delinters the seed goes to the hullers, where the hard outer coats or hulls are broken and the soft, oil-bearing meats are freed. The hulls pass through a second and sometimes a third huller until they are practically free from oil-bearing meat. The meats are then ground through a series of three or more heavy steel rolls, then carried to storage bins, located over the pressroom.

In the United States the seed is usually pressed only once, and when hydraulic presses are used, the seed is heated or cooked before pressing, while in other countries, in the expressing process for the edible oils, several grades are made by re-pressing the same batch of seed.

The "cooking" is accomplished in shallow, steam-heated pans, that are equipped with mechanical stirrers, to mix the meats and prevent uneven cooking. Below these pans sub-heaters are sometimes installed, which are similar to the cookers, and are utilized to hold the cooked batch until the presses are ready to receive it.

The presses are of the "hydraulic type" or of "the expeller type." The press commonly used in America is the "steel box-frame hydraulic type." This press consists of a series of horizontal steel plates that are set one above the other, and is provided with close-fitting steel sides, so that the machine is a series of steel boxes without ends, which are piled one on the other, with the lowest box resting on a hydraulic piston. The

boxes are loaded one after another with cooked meats, that are wrapped in heavy press cloths until the press is loaded. The air under pressure is then applied, and the oil, which is squeezed out, flows down the press sides, and then, via troughs, to the settling cistern. It comes from the press as a dark-red crude oil. It contains some fine meal, and before being pumped from the crude-oil mill to the refinery it is allowed to stand in tanks, to settle out as much of the finer particles as possible.

With the expeller press, which is a continuous working press, the operation is similar to that of a meat grinder. It is simply an interrupted screw revolving inside of a slotted steel barrel. The ground seed is put in through a hopper at one end of the barrel and is pressed toward the opposite end. It is discharged around a cone. This cone can be set in or out of the outlet orifice, so that any desired pressure is obtained. The oil squeezed out by the screw pressure escapes through slips in the barrel, and after settling, and sometimes filtering, is ready for shipment to the refinery.

About 45 gallons of oil per ton of seed handled is the average yield. A large portion of the ground cake and hulls is used as feed or fertilizer. Dirty seed is said to have a tendency to hold more moisture than clean seed, and wet seeds heat rapidly, causing the oil contained to become rancid and fit only for use as soap stock.

Much cottonseed oil is used in the manufacture of lard substitutes, variously known as "Lard Compound," "Vegetable Cooking Compound," "Compound Lard," and generally as "Compound." Some of the compounds are mixtures of lard or lard stearin with vegetable oils. Others contain roughly 12 per cent. of oleostearin instead of lard. The older types that contain animal fats are made by mixing the heated vegetable oil with the proper amount of melted fat, and then running the mixture in a thin layer on large "chill rolls," which are large revolving drums that are kept cold by cold brine within. The compound is thus solidified so quickly that the solid fat does not get time to become free from the oil, and the product is scraped from the roll, conveyed to the fill pipes and into shipping containers. The conveyors are made up as a screw composed of many small paddles, which turn very rapidly and beat the compound, so that it takes up small bubbles of air (approximately 14 per cent.. of its volume), and these small bubbles give the product a pearly white appearance, like lard.

The hydrogenation process, which enables the production of hard fats from liquid oils, permits the replacement of the 12 per cent. of oleostearin, in the lard compounds, with about 5 per cent. of hardened cottonseed or other vegetable oil.

LINSEED OIL.—Linseed oil is obtained from flax seed. This oil is limpid and of a greenish-yellow color, varying in shade depending upon amount of care exercised in pressing the oil and to the degree of refinement. It is soluble in petroleum ether, turpentine, benzol, and, in fact, in almost all solvents.

This oil is used in soap making and is the base of many of the better grades of core oils for foundry use. In some cases it is still used straight for this purpose; also in paints and the manufacture of printing ink and linoleum.

Typical tests of linseed oil:

Specific gravity at 60° F.: 0.932 to 0.938.
Saponification value: 18.9 to 19.5.
Iodine number (Hubl): 170 to 176 per cent.

In America linseed oil is pressed out in open-plate hydraulic presses, with the exception of a few expeller mills.

Abroad, much linseed oil is extracted with benzol or other volatile solvents.

The average American yield is 16 pounds of oil and 36 pounds of cake per bushel of seed, or an oil production of 27 per cent. (U. S. Dept. of Agriculture Bulletin.)

In European countries, linseed oil is a food staple, but in America it is not used for food purposes, although by proper deodorizing and refining it can be so used.

The usual substitutes for linseed oil are soya bean, perilla, fish, corn and china wood oils, for use in paints, varnishes and other manufactured products where linseed oil is used. Tung and perilla oils are the only oils which dry with the necessary tough skin essential for a good, lasting paint oil, but these oils do not make varnishes that are as satisfactory. Corn oil is said to make a better rubber substitute than linseed oil. In linoleums, corn and fish oils have been successfully used in place of linseed oil. Tung oil is said to be better for certain kinds of resin varnishes (those not affected by water) than is linseed oil.

BOILED LINSEED OIL.—In the past the boiled linseed oil was prepared by boiling in open kettles exposed to the air, so as to partially oxidize it, and certain mineral oxides were then added. This oil is used for mixing with paints as a vehicle, and dries down to a film quicker than raw linseed oil.

* At the present time boiled linseed oil is a compound which has been heated to some temperature below the boiling-point and various driers added to it, which are referred to by chemists as catalysts. They are in this case bodies which have the property of taking oxygen from the air and delivering it to the oil, so as to quicken its oxidation or drying.

LINSEED OIL FOOTS.—Generally all linseed oil at the present time is made by the hot pressing process. When it comes from the press the oil contains some fine meal, which settles to the bottom of the tanks and is known as "foots." †

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* NOTE. When the linseed oil has been heated to a high temperature of 130° C. or more, an air current is passed over or through the oil. The temperature is increased until the oil begins to effervesce, due to evolution of decomposed products. The oil absorbs oxygen in this process and thickens. The thickening, or absorption, of oxygen is accelerated by the use of driers such as litharge, manganese dioxide, lead acetate, etc. These substances act as contact substances.

When linseed oil has been boiled until it has lost one-twelfth of its weight, it is the commercial boiled-oil varnish. If heated to lose one-sixth of its weight, it gives a stiff varnish, such as used as the base for printers' ink. The specific gravity of good boiled linseed oil is about .945 to .950.

† See index for printers' ink.

OLIVE OIL.—Olive oil is obtained from olives by pressure. Generally the pulp is put into a tank and pressed. The oil which flows out is called "virgin oil." The portion of the oil which is left in the pulp after pressing is boiled with water and then subjected to a second pressing, and a poor-quality oil is obtained. The best oils are yellowish in color and the poorer oils are greenish-brown. Cottonseed and mineral oils are sometimes used to adulterate olive oil.

Typical physical tests are:

Specific gravity at 60° F.: 0.914 to .919.
Specific gravity at 212° F.: 0.862.
Solidifying point: 22 to 25° Fahr.
Saponification value (Koettstorfer): 18.5 to 19.5 per cent. *KOH*.
Iodine value: 80 to 82 per cent.

The virgin oil is obtained from the first pressing. The "pomace" remaining from the first pressing is re-ground, a little hot water added, and re-pressed to produce the lower grades of oil.

A volatile solvent may be used to extract a very low grade of oil from the last cake. The solvent, usually ordinary gasoline, or abroad, carbon bi-sulphid, is then distilled off. The oil obtained by the carbon bi-sulphid extraction is dark green and has a rank odor and flavor. This process is practised largely in Italy and France, and such oil is imported as "olive oil foots," or "sulphured olive oil." It is used largely for castile soap and other technical purposes, but may be found blended with a highly flavored oil to taste and look like virgin oil.

Olive oil is used as a food and as a medicinal oil. It is also very much in demand for certain forms of wool spinning, and for this purpose an extracted oil, as described, can be used.

PALM OIL.—Palm oil is obtained from the fruits of various kinds of palm trees by the natives of the west coast of Africa. The oil is obtained from the outer pulp of the fruit. The kernel of the nut yields "palm-nut oil."

Palm oil is a solid fat of a consistency of butter, with an orange to a golden yellow color. The typical kinds of palm oil are Lagos oil, which is bright orange; New Calabar, which is golden yellow; Sierra Leone, which is reddish orange. Lagos oil is generally considered the best, because of its low acid content and low consistency. "Salt pond and brass oils," which are brownish-yellow, are also on the market, the "salt pond" being thought to be the poorest quality, as the amount of impurities is high and the free acid high. "Brass oil" contains a high percentage of free fatty acid (50 to 70 per cent.), and is the hardest of the palm oils. Other kinds of palm oil are Half-jack, New Calabar, Bonny, etc.

Physical tests (approximate):

Specific gravity: .905 to .925 at 60° F.
Specific gravity at 212° F.: .8585 to .8590.
Melting point: 80° to 110° Fahr.
Saponification value (Koettstorfer): 20.1 per cent. *KOH*.
Iodine value (Hubl): 51.5 to 52.

Palm oil is crushed by natives, from the fruit from which the palm kernels are obtained, often by treading the pulp with their bare feet, after which the palm kernels are removed. The crushed pulp is then allowed to ferment in pits, and the oil gradually separates and comes to the top, where it is scooped off in gourds and sold. "Chop Oil" is an oil seldom exported, and is used by the Africans as a food oil. It is obtained by crushing and boiling with water some of the best fruit.

The unbleached palm oil is used very largely in the tin-plate industry as a flux on the discharge side of the pots of melted tin, through which the sheet-iron plates are passed to receive thin coats of tin. So far palm oil has been found to be the only satisfactory flux, but it is said that recent experiments with hydrogenated cottonseed oil indicated that this product can replace palm oil in the tin-plate industry.

When used in the production of palm-oil soaps, palm oil can be bleached almost white.

The main grades of palm oils used in this country may be grouped as follows:

(*a*) Genuine Lagos (15 to 25 per cent. free fatty acid).
(*b*) Lagos (20 to 30 per cent. free fatty acid).
(*c*) Lagos Kinds (picked up around the coast).
(*d*) No. 1 Red Palm Oil (Cameroons, Operta, Emo, Bonny) (30 to 40 per cent. free fatty acid).
(*e*) No. 2 Selected Bright Red Oil (Benin, Red Sherbras) (35 to 50 per cent. free fatty acid).
(*f*) No. 3 Palm Oil (New Calabar).

PALM NUT OIL.—This product is generally white to yellowish. Its melting point is about 79° to 85° Fahr. It resembles in some respects cocoanut oil.

Physical tests:

Gravity: .953 to .978 at 60° F.
Specific gravity at 212° F.: .874.
Solidifying point: 79° to 85° Fahr.
Saponification value (Koettstorfer): 24 to 25.8 per cent. KOH.
Iodine value (Hubl): 10 to 15 per cent.

Palm nut, or palm kernel oil, is both chemically and physically similar to cocoanut oil. It is obtained from the palm nut, or palm kernel, which is the hard interior seed of the fruit of a species of palm that grows in Western Africa. It is used interchangeably with cocoanut oil in making vegetable margarines and other food products.

England controls practically the entire world supply of palm kernels.

PEANUT OIL.—May be made by pressing, where sound, sweet nuts are used. Cold-pressed oils are said to be superior for salad oils to those obtained from hot pressing due to the better flavor.

The hot pressing, where the nuts are cooked and pressed at high pressure while hot, gives a larger yield than cold pressing. In France, the usual method is to make virgin oil by cold pressing from the fresh peanuts, and then to hot-press the cold-press cake and the rancid nuts.

Usually the pits and the meat are ground in a suitable mill and the resulting pulp is pressed in large fruit presses, like cider presses. The pulp is wrapped in coarse cloth to form so-called "cheeses," which are stacked in piles in the press, each cheese being separated from the one above by a grating of wooden slats. Comparatively light pressure is then applied.

RAPESEED OIL.—This oil is expressed from the rape seed. The oil may then be subjected to blowing. This is a process of oxidation (limited), which consists in forcing a current of air through the heated oil. The "blowing" process increases the density and the viscosity of the oil and is continued until the desired result is obtained. In some localities the name "Colza Oil" is given to the oil from the original plant and the name of Rapeseed Oil is given to the oil obtained from a developed variety called "Rapo." The oil may be refined to produce a food oil.

RESIN OIL.—This oil is obtained by the destructive distillation of resin. The resin is heated to its decomposing temperature. Vapors are driven off. Among these are the vapors of resin oil. Cast-iron stills are used. A charge is about 3 to 5 tons. Crude resin is brown and viscous liquid. It has a noticeable luminescence of a bluish or violet tinge. If heated to a temperature of 300° Fahr. for several hours the crude resin oil loses about 40 per cent. of its volatile constituents and becomes greenish. This can be removed by treatment. The finished oil is pale brown. It is a drying oil.

Mr. Alfred R. Lange, B.Sc., has recorded the changes in the chemical and physical properties of resin which has undergone destructive distillation without access to air. These changes were printed in *The Oil, Paint and Drug Reporter,* March 17, 1919, as follows:

Mr. Lange has endeavored to carefully note the changes that occur and the following tests are carefully determined observations of the several redistillations of resin. The resin used was commercial "B" grade. The percentage of resin acids is obtained by using a neutralization value of 162 mg. *KOH* per gram; the iodine value was determined by means of the Wijis solution, whereas the index of refraction was obtained by use of the Zeiss instrument.

It will be observed that the following changes are definite:

(*a*) The amount of resin acids present in the successive distillations decreases, this due to the decomposition of the acid into hydrocarbons.

(*b*) The specific gravity decreases.

(*c*) The solubility in alcohol decreases as the amount of resin acid decreases, in proportion to their percentage, being practically insoluble in the last distillations, which are almost pure hydrocarbons.

(*d*) Color of successive distillations becomes lighter. Whereas the first distillation of the solid resin yielded the commercial kidney resin oil with its peculiar bloom, the sixth distillation yielded a very pale yellow oil with a mineral oil fluorescence.

The variations in the iodine and refraction values are not along any fixed rule; the formation of new hydrocarbons with subsequent change in the molecular construction of the new compounds brings about new conditions that govern the properties as regard these two values:

Material.	Resin acids.	Specific gravity.	Iodine value.	Yield.
"B" resin		1.010 /60° F.	128% (1 hour)	....
First distillation	40.70%	1.0085/77° F.	115% (75 min.)	98%
Second distillation ...	26.38%	.9973/74° F.	112% (75 min.)	97%
Third distillation	18.35%	.9871/79° F.	106% (75 min.)	97%
Fourth distillation	7.60%	.9775/76° F.	107% (75 min.)	95%
Fifth distillation	3.17%	.9726/78° F.	85% (75 min.)	93.5%
Sixth distillation	1.16%	.9678/84° F.	103% (75 min.)	95.8%

Color.	Nature of residue.	Index of ref.	Solubility.
"B" resin		Solid	Soluble in 95% alcohol
Dark red	Coke	Indefinite	Soluble in 95% alcohol
Brilliant red ..	Coke	1.54643/23° C.	Trifle insoluble in above
Light red	Coke and tar	1.5491/23° C.	Almost insoluble in water
Dark yellow ..	Tarry	1.5476/23° C.	Insoluble in above.
Light yellow ..	Tarry	1.5469/23° C.	Insoluble in above.
Pale yellow ...	Tarry	1.5464/23° C.	Insoluble in above..

GUMMING.—Drying or gumming is usually caused by the gradual conversion of vegetable oils into resin. It goes on rapidly with drying oils and slowly with non-drying oils, or fixed oils.

SOYA BEAN OIL.—Soy or Soya Bean Oil is a member of the group of " drying " oils, and resembles the properties of linseed and other drying oils more closely than peanut, cottonseed or similar semi-drying oils.

It is eaten in China and Asia, and when well refined is bland.

In general, cottonseed mills can handle soy beans with little or no change of equipment. Soy Bean Oil is generally not refined when to be used for paint-mixing and industrial requirements. It must be refined and deodorized before being suitable for food.

MISCELLANEOUS VEGETABLE OILS.

MUSTARD OIL is closely related to rape oil. It is obtained from mustard seeds. Part of this oil is obtained as a by-product in manufacturing mustard flour and prepared mustards.

SESAME OIL.—This oil is obtained from the sesame seed, known in Mexico as " Ajoujoli." It is used as a food oil in parts of Europe.

SUNFLOWER SEED OIL.—This oil has a pale yellow color, a mild taste and a pleasant odor. The cold-pressed oil is used in Russia for a butter substitute. The hot-pressed is used in soap making and in some varnishes. It is also used in Russia as a burning oil.

CANDLE-NUT OIL.—This oil is obtained from a plant closely related to the tung nut. It is similar to tung-nut oil, but is said not to be as good a drying oil.

SHEA-NUT OIL.—This is in the form of a semi-solid fat and resembles cocoanut oil. It is used in the soap industry, and is obtained from the fruit kernel of an African tree.

CARNAUBA WAX.—This is a brittle, yellowish wax, largely used in candle manufacture and in certain forms of polishes. Its melting point is about 180°–190° Fahr., and its specific gravity is about .998. It is secured from the carnauba palm leaves.

BEN OIL.—This is an oil used by perfumery manufacturers for extracting odors. It is also used as a clock and light machinery lubricant. It is colorless and odorless, and does not turn rancid easily.

ANIMAL OILS

GENERAL PROCESSES.—Pure animal fats are usually obtained by mincing or chopping the tissues in which they are contained, and then rendering, by heating, until the melted fat separates out. After the free, separated fat has been drawn off, the "cracklings," or cooked tissues, are generally pressed to recover as much as possible of the fat.

BONE TALLOW.—This product is generally used by manufacturers of cheap soap. It is sometimes called " Bone Grease." This grease or fat is extracted from bones, such as cow's and bullock's shank bones. It is generally sold in the form of a grayish. soft fat of granular nature. It may contain some water, animal tissue, free acid ranging from about 6 per cent. to 20 per cent., about 75 per cent. to 90 per cent. of saponifiable oil and some phosphate of lime, in small quantities.

DEGRAS, YORKSHIRE GREASE, OR WOOL GREASE.—The raw wool from the sheep's back contains many impurities, which are washed out in the scouring. There is some earthy matter, soapy matter and other matter, called " yolk," etc. (See index.) When the raw wool is washed these impurities pass into the waste liquor, and the liquor is, therefore, very rich in grease. There are several ways of recovering this grease. One method is to warm the liquor with hydrochloric acid, which decomposes the soaps present and the fatty contents, which rise to the surface and can be collected after the liquor is allowed to cool.

The crude grease, which is skimmed off the top, contains impurities in the form of wool fibres, dirt, etc. It is filtered to remove the water, and pressed through cloth, when the solid matter and the fat are separated. The fat is known as wool grease, brown grease, degras, etc. It is a thick, smooth, or semi-fluid product.

The grease is recovered from the milling and fulling of the wool, after the waste-soap liquor is handled as above, and gives a better and purer grease than is extracted from the waste liquor, obtained after the raw wool is washed.

A typical method for refining the grease is to distil it in a cast-iron still with fire and steam. The water comes off first, then a thin oil, followed by a greenish oil or grease, and finally a thick oil or pitch remains in the still.

From the first light oil olein and stearin may be obtained by pressure, or it may be redistilled, giving a better colored product and one of higher quality.

The grease runs from light or pale, to dark brown or practically black. It forms very staple emulsions with water.

Degras is used in making wool oils, apron oils, stuffing leather, as a compound for cylinder oils, etc. A purified form is known as " lanolin,"* and is used as a base for ointments.

HORSE OIL OR HORSE FAT.—This fat is produced from the carcasses of horses that have been killed for meat or otherwise destroyed. It is often used in producing so-called " commercial neatsfoot oil," which may be little else than wintered horse oil.

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* NOTE. The lanolin yielded when the fatty matter is purified from fatty acids has the property of taking up large quantities of water in an emulsion.

Horse fat is claimed to have special properties for making many types of lubricating greases, and is supposed to be superior to any other fat for making petroleum lubricating greases.

LARD OIL.—This oil is extracted from layers of fat called "leaves," which are taken from the loins of the hog. It is placed in cloth bags and pressed (best grades).

Other grades are obtained by boiling in water the fats and tissues surrounding the abdomen. The lard is skimmed from the surface and kept warm for several hours to allow the tallow to crystallize. This process is known as "seeding." The seeded lard is then strained with cloth strainers and pressed, producing lard of commerce.

The main grades of lard oil are as follows:

(*a*) Prime Winter Strained.
(*b*) Prime.
(*c*) Off Prime.
(*d*) Extra No. 1.
(*e*) No. 1.
(*f*) No. 2.

The chief differences in the different grades are the per cent. of fatty acid contained and the color. It may run up to 30 per cent. fatty acid (free). It should never be more than 15 per cent. for lubricating purposes. The temperature of solidification varies greatly. Some grades will deposit a fatty material, known as "Stearin" at ordinary room temperatures and will become stiff at 50° Fahr.

Lard oil saponifies quickly.

For lubricating and textile purposes the lard oil should never be made from "lard of mast" or distillery-fed hogs. Oil made from old lard should not be used, as it will give trouble from gumming. The color varies from pale straw to brownish red.

Some lard makers cook the hog fats under pressure with live steam, blown directly into covered tanks, instead of heating the fats dry in steam-jacketed kettles. This process gives what is known as "steam lard," while the former process gives "kettle-rendered lard."

"Prime steam lard" is different from "kettle-rendered lard" in that in the packing houses, which produce about one-half of the domestic lard, and generally of a grade known as "prime steam lard," only the "leaf" and "back" fat are kettle-rendered, all of the other fats going into steam lard. The small hog raisers, packers and butchers usually make kettle-rendered lard.

In making kettle-rendered lard, the leaf fat is pulled from the hog carcasses while they are still warm and quickly chilled. When cooled, the fat tissue is minced finely and heated in steam-jacketed kettles until a clear fat, in the form of a light-yellow oil (at this temperature about 250° F.), separates out from the tissues. It is then salted and allowed to stand till fine particles of the fat membranes separate out. After one or more settlings it is drawn off hot and put in containers in a freeze. The "cracklings" which are left in the kettles are either pressed to get the remaining lard or are put into the steam lard tanks.

"Neutral lard," sometimes called "Neutral," is made from the first grade of leaf fat by cooking as for kettle-rendered lard, but at a lower temperature of from 126° to 128° F., so that it retains little of the hog flavor.

Steam lard is rendered by live steam from the chopped fats that are charged into large steel tanks, the steam being introduced into the tanks at the bottom. When cooking has caused the melted lard to separate, the steam is turned off and the water and solids settle, so that the lard can be drawn from the top of the water and the tankage dumped.

The lard is darkened during the cooking, and it is, therefore, bleached and deodorized before marketing.

Lard oil is made by chilling lard and often other fats, such as horse oil, and pressing out the liquid olein from the higher melting stearin. The olein constitutes the lard oil.

Navy Department Specifications for Lard Oil (14 O, 7a.) Oct. 1, 1915.
(For Pipe Cutting and Threading Purposes)

GENERAL INSTRUCTIONS

1. General Specifications for the Inspection of Material, issued by the Navy Department, in effect at date of opening bids, shall form part of these specifications.

COMPOSITION

2. Shall be a clear, light yellow lard oil of good quality, free from rancidity or adulteration. It shall not contain more free fatty acid than 5 per cent. of oleic acid.

TESTS

3. The specific gravity at 15° C. shall be not lower than 90 per cent. or higher than 92 per cent. It shall flow at 8° Centigrade or below. Its viscosity at 38° C. shall not exceed 220 seconds in a Saybolt viscosimeter having a water rate of 30 seconds at 15° C.

DELIVERIES

4. Deliveries shall be made in 50-gallon well-coopered casks.

NEATSFOOT OIL.—This oil is commercially obtained from the feet of sheep, hogs, horses, etc., not always from cattle. The feet are scalded to loosen the hoofs, pulled out and feet are boiled. The oil rises to the surface and is skimmed off. It is screened, dried and filtered. The reason for removing the hoofs is to prevent darkening of color of the oil. With proper care the fatty acid is generally less than 1/2 per cent. It may run as high as 25 to 30 per cent.

Its color is light straw to dark straw. It has no odor when fresh. Its cold test is about 32° F. It has little tendency to go rancid.

U. S. Navy Specifications for Neatsfoot Oil (14 O, 3a) Jan. 2, 1917
General Specifications

1. General Specifications for Inspection of Material, issued by the Navy Department, in effect at date of opening of bids, shall form part of the specifications.

QUALITY

2. Neatsfoot oil must be free from admixture of other oils, and must not contain more acidity than the equivalent of 2 per cent. of oleic acid.

COLD TEST

3. It must have a cold test below 25° F., as determined in the following manner: A couple of ounces of the oil will be put into a 4-ounce sample bottle and a thermometer placed in it. The oil will then be frozen, using a freezing mixture of ice and salt if necessary. When the oil has become hard the bottle will be removed from the freezing mixture and the oil allowed to soften, being stirred and thoroughly mixed at the same time by means of the thermometer until the mass will run from one end of the bottle to the other. The reading of the thermometer at this moment will be taken as the cold test of the oil.

RED OIL.—This is known by some users as "Elaine." It is practically pure oleic acid. It is semi-solid, resembling tallow somewhat. Distilled red oil is ruby-colored, and is used in soap making and in the manufacture of wool oils. It is obtained by decomposing a solid fat and collecting the freed fatty acids, by solidifying and pressing, as a by-product; such as, for example, would be obtained in the manufacturing of glycerin and stearic acid from tallow.

The name "Oleic Acid" is also used for this product, and it may either be termed as "saponified" or "distilled," the latter type being obtained by melting fats or oils, mixing with them a percentage of sulphuric acid, and then distilling with the aid of superheated steam. The water containing the glycerin and the fatty acid distils over. The mass of the fatty acid is then separated into oleic acid and stearic acid or stearin by gentle heating.

STEARIN.—When melted tallow is allowed to cool slowly at a temperature of from 70° to 85° Fahr. it forms a granular mass. The stearin separates out and can be removed by pressing. This process is referred to as "seeding." The liquid that passes through is called "Tallow Oil." (See tests in table.)

TALLOW.—Tallow is derived from the fats of cows, oxen, sheep, goats and similar animals. The tallow is found in small cells of animal tissue. "Rendering" is the process of extracting the tallow from the rough fat. The tallows from different parts of the world are slightly different, and commercially, tallows are distinguished according to the country from which they come and their source; that is, whether it is cattle, sheep, "beef," "mutton," etc. Generally "beef" tallow is used in America. South America produces both mutton and beef tallow. Beef tallow comes from oxen; mutton tallow from rams, bucks, ewes, she goats.

The chemical composition of tallow consists essentially of the two glycerides, olein and stearin. In the soft tallow the stearin predominates, forming about 60 per cent.; and in the hard tallow stearin also predominates, being about 80 per cent. Beef tallow contains more olein than mutton tallow. Tallow also contains palmatin.

Pure tallow is firm and white and free from odor.

Adulterated tallow is usually composed of tallow and bone grease, cottonseed oil, stearin from wool grease, etc.

Tallow is used in the manufacture of some lubricating greases, and is of value in the lubrication of bearings carrying heavy loads. It is also used for sizing cotton yarns, and for soap making and candles.

The physical tests of beef tallow are approximately as follows:

Specific gravity: 0.940 to 0.955 at 60° Fahr.
Specific gravity at 212° F.: =.863.
Melting point: 105° F. to 115° F.
Cold test (solidifying): 98° F. to 100° F.
Saponification (Koettstorfer): 19.3 to 20 per cent. *KOH*.
Iodine value (Hubl): 35 to 43 per cent.

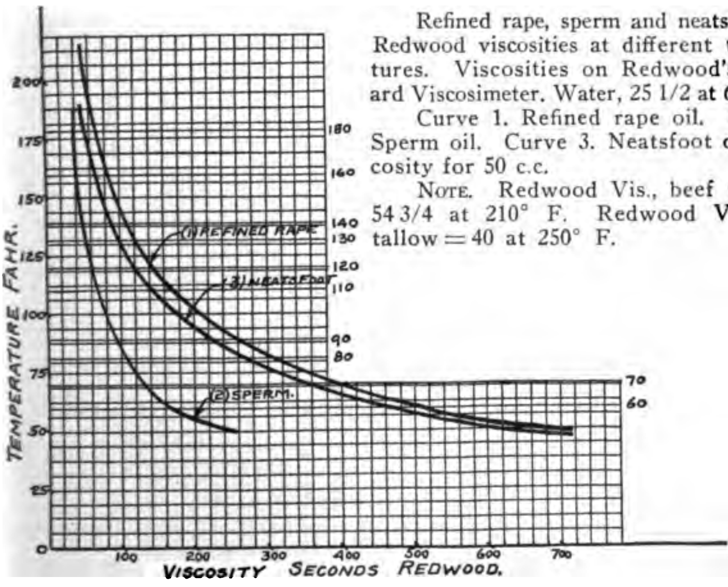
When to be used for lubrication, tallow must be made from fresh fats which have not had time to decompose.

TALLOW OIL.—This oil is manufactured from the tallow of beeves by pressure. It has many similarities to neatsfoot oil. Stearin is obtained from it by slow cooling and straining.

GENERAL TESTS AND CHARACTERISTICS OF FATTY OILS AND FATS

VISCOSITIES OF SPERM, NEATSFOOT AND REFINED RAPE OILS.—As an indication of the behavior of these oils as to their viscosities when the oils are heated, the curve shown in Fig. 3, Sec. 5, is included. The viscosities are taken on a Redwood Viscosimeter. As is shown, the viscosity of sperm oil varies through a much smaller range between the temperatures of 75° and 175° Fahr. than do the viscosities of the other oils.

TABLES OF TESTS AND CHARACTERISTICS OF VARIOUS FATTY OILS.—The following tables give some average tests of commercial samples of various fatty oils. It must be remembered that the qualities vary widely in these oils and fats, and, therefore, the values given in the tables are average approximate values in the majority of cases:



Refined rape, sperm and neatsfoot oils. Redwood viscosities at different temperatures. Viscosities on Redwood's Standard Viscosimeter. Water, 25 1/2 at 60° Fahr.

Curve 1. Refined rape oil. Curve 2. Sperm oil. Curve 3. Neatsfoot oil. Viscosity for 50 c.c.

NOTE. Redwood Vis., beef tallow = 54 3/4 at 210° F. Redwood Vis., beef tallow = 40 at 250° F.

FIG. 3. SEC. 5.

GENERAL TESTS, FATTY OILS AND FATS

Name of oil or fat	Gravity Baumé	Gravity Specific	Flash Fahr.	Viscosity Saybolt at 100° F	Viscosity Saybolt at 212° F.	Cold test Fahr.	Per cent. free fatty acid	Saponification value	Iodine number	Color	Notes
No. 3 Castor.....	15	....	485 Fire 550	......	160	0	3.21/3.77	......	92.3	Greenish	Commercial grade.
Castor (Gold Bond)	15	....	545 Fire 600	......	110	0	0.57	......	....	Practically none	Chemically pure.
Castor (A. A.)...	15	....	....	....	....	−1	0.36/0.53	185	83/86	Practically none	Chemically pure.
Castor (A. A.)...	15.33	....	475	1377	110 (at 300° F. =60 Say.)	....	....	......	....	Colorless	Conradson carbon 0.18
Cocoanut (Cochin)	......	0.936	......	......	....	Melts 70° to 80°	1.25/2.75	25/26	89/93	White soft fat in our climate	Odor pleasant and characteristic. Odor more pronounced, as when rancid.
Cocoanut (Ceylon)	......	0.923	......	......	....	Solidifies 60° to 70° Same	1.15/18.5	25/26	10.4	Water white oil when melted	Other grades from Malabar, Manila, Fiji Islands, Mauritius, etc.
Corn............	21.3/22.0	....	480+	175/185	....	Solidifying point 14°–15° F.	0.4/0.6	184/191	115/123	Pale to gold, yellow	
Cottonseed (Summer yellow)	21.8/22.0	....	550+	168/179	....	28−	1−	191/195	106/108.5	Yellowish to brownish	Blown Cottonseed sample had iodine value of 56.6.
Cottonseed (Summer white)	22.0	....	590+	169/179	....	30−	0.1/0.3	191/196	....	Yellowish	
Cottonseed (Crude)	21.3	....	480+	179	....	30−	2.9/7.5	191/196	102/115	Brownish yellow	
De Gras (typical) Yorkshire grease, wool grease, etc.	......	0.901 to 0.957	435+	......	....	Melting point about 100 to 110° F.	18.0/27.0	99/102	About 26	Light brown or dark to almost black	Unpleasant, distinctive odor; readily mixes with water forming emulsions.
De Gras or wool fat (neutral)	15.5/20.0	....	500	......	....	Melting point 88° to 106° F.	0/3.5	60/85	197/227	....	
Distilled wool grease	......	....	......	......	....	....	About 50	......	....	....	About 38 per cent. unsaponifiable matter.
De Gras (French) sod oil	......	0.993	......	......	....	48–53	10 to 35	......	....	Light to dark brown	A by-product of currying leather, about 18 to 40 per cent water.
Elaine or red oil..	......	0.900	335+	110	....	50 or better	80/96	200	90 (pure acid)	See notes	Semi-solid, resembling tallow. Distilled red oil ranges in color from brown to ruby.

Fish or Menhaden (winter pressed)	20.5	....	446/465	125/135	....	30/35	6 per cent or better	......	....	Light brownish	The viscosity of the oil if it contains "foots" may be higher, ranging generally about 170 at 100° F.
Fish (yellow bleached)	20.8/21.8	....	410/470	138	42	30/35	....	189/193	139/158	Yellowish-amber	Fish oil may be "blown." A sample of blown oil had 10° B. gravity and 325° Vis. at 100° F.
Horse fat........	23.6	....	430+	......	....	Usually melts at about 107° F.	8–23.5	196/197	75/85	Brown.	
Horse oil (blown)	......	....	430+	......	....	60	....	......	90/115		
Horse oil........	22.5	0.918/0.921	......	......	....	....	14.5	196	90/115		
Lard oil: Extra winter strained, steam rendered, prime	22.8	....	560+	205/215	....	30–40	3 or less	192/198	64/75	Nearly colorless	
Lard oil: Prime, winter strained	22.5/23.0	....	585+	218/224	....	30–40	5 or less	196/199	67/75	Yellowish, nearly colorless.	
Lard oil: Extra No. 1	23.0/23.2	....	450+	200/205	....	35–50	15 or less	196/199	68.1/73.0	Yellowish to amber.	
Lard oil No. 1....	22.5/23.2	....	440+	200/205	....	35–50	22 or less	196/199	64.4/72.5	Yellowish to red amber.	
Lard oil, No. 2...	22.7/23.0	....	420+	......	45	....	35 or less	199	60	Red amber to ruby.	
Linseed (raw)....	18.5/21	.9319	500+	130	....	0	0.9/6.0	106/193	170/193	Golden yellow.	
Linseed (boiled)..	19.0/20.0	....	442+	171	....	0	3.9/8.0	190/195	178/190	Yellowish to brownish.	
Neatsfoot, extra, unpressed, prime	......	....	......	......	....	45	1 to 2	......	....	Pale yellowish	Does not turn rancid readily.
Neatsfoot prime..	......	....	......	......	....	40–45	5	......	....	....	
Neatsfoot (25° winter, pressed, extra prime)	......	....	......	......	....	20–25	1 to 2	......	....	....	
Neatsfoot (35° winter pressed, extra prime)	......	....	......	......	....	30–35	1 to 2	......	....	....	
Neatsfoot, No. 1.	23/23.6	....	410+	215/227	....	40/45	9.7/17.5	194/196	66.4/76	Yellow.	
Neatsfoot (extra white)	22/23	....	475+	......	....	36–48	0.8/6.7	196	....	Pale yellowish.	
Olive, commercial	22.3	....	450+	214	49	10–25	3.5/30.0	187/196	79.2/82.9	Greenish yellow.	
Olive (edible)....	22.0	....	450+	177	....	23–30	2 or better	190	80/83	Yellowish greenish	
Palm (Lagos)....	......	0.925	......	......	....	Melting point about 80 to 107	About 10 to 14	201/215	51/54	Bright orange	Best, most neutral. Impurities usually less than 2 per cent. Softest.
Palm (Salt pond).	......	....	......	......	....	....	As high as 80	......	....	Brownish yellow	Very poor quality.
Palm (NewCalabar)	......	....	......	......	....	......	...	......	....	Golden yellow.	

Palm Nut.......	......	0.950	......	......	....	Melts 78–86	8 or better usually	24	10/13	White to faint yellow	Consistency like butter. Largely used in soap making in place of cocoanut oil.
Peanut..........	22.5	0.918	580+	330	....	35	0.26+	189/196	98/105	White to yellowish.	
Rape (refined)...	......	.9147/.916	540	260	0	10–30	1.4/6.25	112	101	Pale yellow	Shirashime (Japanese) has peanut smell. Ravison (East Indian) has onion smell. Ravison has better burning qualities.
Rape (Colza)....	......	0.914	......	......	....	18	05./4.2	168/178	103/105	Pale yellow	
Resin (4th rim oil)	10.2/13.5	....	......	230	....	15+	10% free resin acid	20.0	23	....	
Resin (kidney)...	6.0/8.0	....	......	......	....	55	49/56 free resin acid	......	....	....	
Resin oil........	8	....	270	......	63	24	30	48.5	....	Red amber	Syrupy with resin smell.
Sperm (winter bleached)	29.4/29.7	....	485+	95/115	....	About 40	.4/4.6	115/138	81.7/85	Pale, clear, bright.	
Seal (light refined)	21.3/25	....	515+	150/165	....	10/25	0.25/0.9	178/196	124/148		
Soya bean.......	21.5	....	......	......	....	....	....	191/192	124/141	Pale yellow to green.	
Tallow oil.......	23/23.5	....	570+	225	44/54	45/80	1 or better	190/197	56/57	Yellowish to whitish.	
No. 1 Tallow....	20.5	....	......	......	....	90/100 melts	3/4.5	196	48.7/56	Yellowish.	
Whale oil (No. 3 bleached)	20.8	....	494+	191	25	....	2.13	189	131.8	Dark yellow	From blubber, clear and bright fishy odor, nutty taste.
Wood (China) oil.	18.5/19.0	....	......	......	....	....	6	190/195	165	Pale yellow to brown	Pressed from "tung nut" Japan, Manchuria; light changes it slowly to solid fat. Dries rapidly, faster than linseed.
Turpentine (gum)	......	0.862/0.875	Boiling point 315° F. Flash 104° F+	......	....	....	....	......	....	Water white	95 per cent. should distil between 309° F. and 330° F. No grease spot should remain from drop on piece of paper when allowed to evaporate.

SECTION 6

TESTING AND PROPERTIES

TESTING PETROLEUM PRODUCTS

In the past, physical tests were used as a deciding factor in the selection or rejection of lubricating and industrial oils, and an attempt was made to arbitrarily designate certain definite physical and chemical properties that the oils were expected to possess to satisfy a given mechanical or industrial requirement.

It is unfortunate that oils lend themselves so readily to a number of scientific tests, because, due to this fact, these tests have become the common property, to a very considerable extent, of operating engineers, oil salesmen, purchasing agents, and others who are not equipped with sufficient knowledge of the refinement of oil to appreciate what the tests really signify. The result has been that in the present day, when petroleum oils are made from many different crudes, each crude producing oils having individual characteristics, the trade has become so confused and the selection of an oil for any purpose so difficult, that an economical and efficient choice is largely a matter of luck.

The physical tests generally met with in the sale, application, and purchasing of lubricating and industrial oils other than fuel oils, fixed oils, gasoline, burning oils, etc., are as follows: Viscosity, Cold Test, Gravity, Flash-point, Fire-point, Evaporation Test, Acidity Test, Test for Tarry Residues, Test for Compound Oils, Gumming Test, and Deëmulsibility Tests.

Also, in some cases, with lubricants, Friction Tests. Tests for fuel oils and other oils are described elsewhere.

GRAVITY

SPECIFIC GRAVITY.—The specific gravity of a substance is its weight, as compared to the weight of an equal bulk of pure water. Let W equal the weight of the body in the air, and P equal the weight of the body submerged in water, then:

$$\text{The specific gravity} = \frac{W}{W-P}$$

For obtaining gravity (specific) of liquids, Westphal's Balance may be used. A view of this instrument is shown in Fig. 1, Sec. 6.

FIG. 1. SEC. 6.—Westphal's balance for liquid.

FIG. 2. SEC. 6.—Young's gravitometer for solids.

For obtaining the specific gravity of solids, Young's Gravitometer (patented) may be used. A view of this instrument is shown in Fig. 2, Sec. 6. It reads directly in specific gravity, without calculations, and has a scale graduated to read specific gravities from 0.85 to 10.0.

Another form of Young's Gravitometer (patented), for obtaining the specific gravity of liquids, is shown in Fig. 3, Sec. 6. This shows specific gravities on a direct reading scale, without adjusting riders along a beam, as in the Westphal type.

SPECIFIC GRAVITY.—(Testing methods, U. S. Division Military Aeronautics, acknowledgment to A. S. T. M.) Specific gravity may be determined by hydrometer, Westphal Balance, or pycnometer, providing these instruments are verified. The observation shall be taken with the sample at 15.56° C., compared with water of the same temperature. Cor-

rection for the buoyant effect of the atmosphere must be made when necessary. (Degree Baumé may be obtained through use of the formula adopted by the Bureau of Standards, which is $\frac{140}{\text{Sp. Gr.}} - 130° = B°$.)

FIG. 3. SEC. 6.—Young's gravitometer for liquid.

Another gravity scale, Petroleum Association (S. V.), uses the modulus 141.5 for converting specific gravity to degrees Baumé. The oil trade extensively uses this modulus, *viz.:*

$$\text{Specific Gravity (60/60° F.)} = \frac{141.5}{131.5 + \text{Bé.}}$$

$$\text{Baumé Scale at 60° F.} = \frac{141.5}{\text{Sp. Gr.}} - 131.5$$

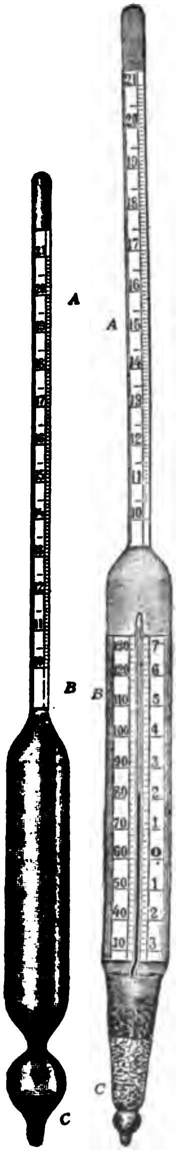


FIG. 4. SEC. 6.—Hydrometers with Baumé scales.

BAUMÉ GRAVITY AND THE HYDROMETER.—In the oil trade, gravity is usually taken with the hydrometer. A hydrometer is usually made of glass and consists of three parts (Fig. 4, Sec. 6). A is the upper part or graduated scale on which the readings are taken, B is the bulb or enlargement of the tube containing air, C is a small bulb at the bottom of the tube, containing shot or mercury to weight the tube. The upper scale is graduated to read directly in specific gravity, or it is divided into an arbitrary scale, called *Baumé Gravity*. The trade generally use the Baumé hydrometer for all oil gravities.*

The standard temperature at which gravity should be referred to is 60° Fahr. Increase in temperature decreases the specific gravity readings, and suitable correction must be made in the readings obtained by the hydrometer to allow for the number of degrees the oil temperature exceeds or is below 60° Fahr.

With this scale the gravity of water is 10, at the standard temperature of 60° Fahr. The lighter the oil is in body the higher the Baumé reading. For instance:

Water	10
Cylinder Oil	24–27
Heavy Engine Oil	18.5–28
Light Engine Oil	21.5–31

READING THE HYDROMETER.—(U. S. Bureau of Standards, Circular 57, pp. 4, 5). "The correct method of reading the hydrometer is illustrated in Fig. 5, Sec. 6, and Fig. 6, Sec. 6. The sample of oil is placed in a clear glass jar, or cylinder, and the hydrometer carefully immersed in it to a point near to that to which it naturally sinks, and is then allowed to float freely." "The reading should not be taken until the oil and the hydrometer are free from air bubbles and are at rest. When reading, the eye should be placed slightly below the plane of the surface, Fig. 5, Sec. 6, and then slowly raised until this surface, seen as an ellipse, becomes a straight line. The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument, Fig. 6, Sec. 6.

"Specific gravity, as used in the U. S. Standard tables in the above-mentioned circular, is defined in the circular as 'the ratio of the weight (in vacuo) of equal volumes of oil and water at 60° F.' That is, the true and not the apparent specific gravity is employed in these tables. The weight per gallon of oil is the apparent weight of a volume of oil 231 cubic inches at 60° Fahr. when weighed in air of 50 per cent.

* American practice.

humidity, at the same temperature as the oil and at a pressure of 760 mm. of mercury. The weight of a gallon of water at 60° Fahr. is as follows: In air, 8.32823 pounds; in vacuo, 8.33722 pounds."

The hydrometer should be inserted carefully, so that the force of its plunge does not cause the instrument to dip too far into the oil, allowing

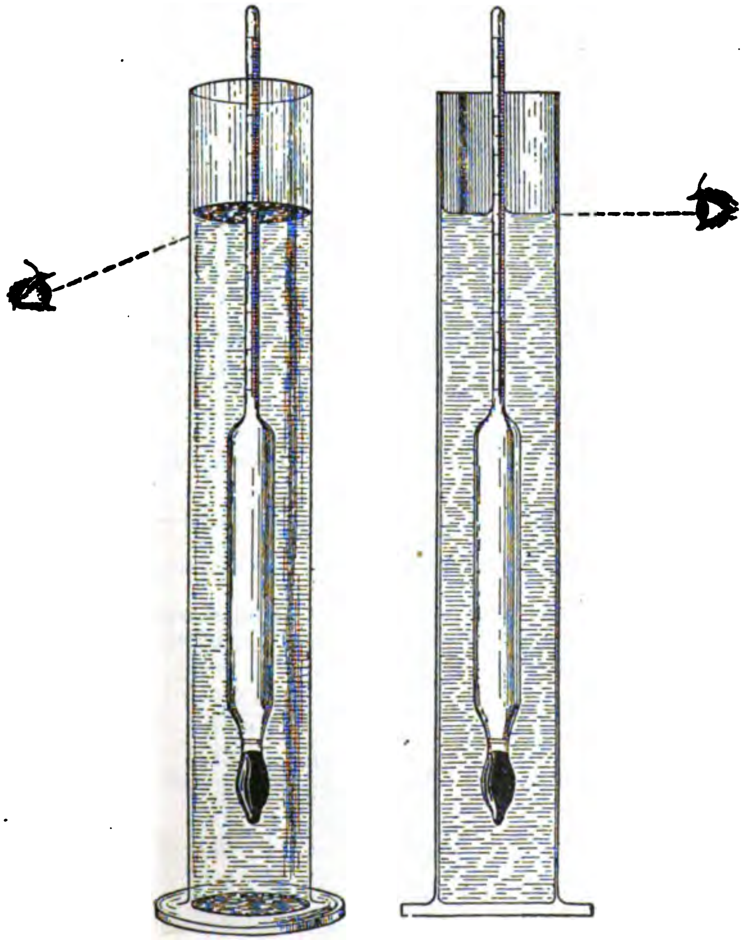


Fig. 5. Fig. 6.

Figs. 5 and 6. Sec. 6.—Method of reading the hydrometer as described in Circular 57, U. S. Bureau of Standards.

it to rebound and carry back some of the oil adhering to the stem, which would affect the reading by placing this additional weight upon the hydrometer. If the oil is transparent, note the lower meniscus, and if not transparent, allow for capillary attraction and note the point where the oil surface would have struck the stem of the hydrometer.

VALUE OF GRAVITY TEST.—The only practical value of the gravity test is the determination of the source of the crude from which the oil was made. Oils made from asphaltic base crudes, such as Texas and California oils, will range from 7 to 10° Baumé lower than oils made from paraffin base crudes.

Gravity has no effect upon the lubricating merits of an oil, and, as a matter of fact, ordinary machine oils will show a wide range of gravities, even though coming from the same crudes

Gravity serves, to some extent, in checking current deliveries of a certain brand of oil, by maintaining the uniformity of the deliveries.

The refiner will not usually guarantee the exact gravity of any brand of oil, because current deliveries coming from different batches of the same crude and with the same method of distilling will show some variation. The gravity of an established brand of oil is usually fixed between definite limits. Mineral oil is not a fixed chemical body of unchangeable character, and if the buyer insists on an exact and definite gravity, the oil is simply blended and doctored to obtain this gravity. It is always well, therefore, to allow a reasonable range for the gravities of an oil, giving a high and low limit.

COMPARISON OF SPECIFIC AND BAUMÉ GRAVITIES (FOR LIQUIDS LIGHTER THAN WATER).—The relation of specific gravity readings to those of the Baumé scale is given by the following formula:

$$\text{Specific gravity at } 60^\circ \text{ F.} = \frac{140}{130 + \text{Baumé reading.}}$$

$$\text{Baumé gravity} = \frac{140}{\text{Specific gravity at } 60^\circ \text{ F.}} - 130$$

The above is the Baumé scale adopted by the Bureau of Standards (Circular No. 57).

The National Petroleum Association at its Pittsburgh Meeting, April 21–22, recommended the following scale, which is based on the modulus 141.5, widely used by the oil trade, as follows:

$$\text{Specific Gravity at } 60^\circ \text{ F.} = \frac{141.5}{131.5 + \text{Bé.}}$$

$$\text{or Baumé } (60^\circ \text{ F.}) = \frac{141.5}{\text{Sp. Gr. at } 60^\circ \text{ F.}} - 131.5$$

BUREAU OF STDS. MODULUS. Basis (Sp. Gr. at 60° F. =

*SPECIFIC GRAVITIES, POUNDS PER GALLON, AND (PER POUND, CORRESPONDING TO THE VARI(DEGREES BAUMÉ DESIGNATED

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pound per gallon
[illegible]	1.0000	8.328	0.1201	15.0	0.9655	8.041
[illegible]	.9993	8.322	.1202	15.1	.9649	8.035
[illegible]	.9986	8.317	.1202	15.2	.9642	8.030
[illegible]	.9979	8.311	.1203	15.3	.9635	8.024
[illegible]	.9972	8.305	.1204	15.4	.9629	8.019
[illegible]	.9964	8.299	.1205	15.5	.9622	8.013
[illegible]	.9957	8.293	.1206	15.6	.9615	8.007
[illegible]	.9950	8.287	.1207	15.7	.9609	8.002
[illegible]	.9943	8.281	.1208	15.8	.9602	7.997
[illegible]	.9936	8.275	.1208	15.9	.9596	7.991
[illegible]	.9929	8.269	.1209	16.0	.9589	7.986
[illegible]	.9922	8.263	.1210	16.1	.9582	7.980
[illegible]	.9915	8.258	.1211	16.2	.9576	7.975
[illegible]	.9908	8.252	.1212	16.3	.9569	7.969
[illegible]	.9901	8.246	.1213	16.4	.9563	7.964
[illegible]	.9894	8.240	.1214	16.5	.9556	7.959
[illegible]	.9887	8.234	.1214	16.6	.9550	7.953
[illegible]	.9880	8.228	.1215	16.7	.9543	7.948
[illegible]	.9873	8.223	.1216	16.8	.9537	7.942
[illegible]	.9866	8.217	.1217	16.9	.9530	7.937
12.0	.9859	8.211	.1218	17.0	.9524	7.931
12.1	.9852	8.205	.1219	17.1	.9517	7.926
12.2	.9845	8.199	.1220	17.2	.9511	7.921
12.3	.9838	8.194	.1220	17.3	.9504	7.915
12.4	.9831	8.188	.1221	17.4	.9498	7.910
12.5	.9825	8.182	.1222	17.5	.9492	7.904
12.6	.9818	8.176	.1223	17.6	.9485	7.899
12.7	.9811	8.171	.1224	17.7	.9479	7.894
12.8	.9804	8.165	.1225	17.8	.9472	7.888
12.9	.9797	8.159	.1226	17.9	.9466	7.883
[illegible]	.9790	8.153	.1227	18.0	.9459	7.877
[illegible]	.9783	8.148	.1227	18.1	.9453	7.872
[illegible]	.9777	8.142	.1228	18.2	.9447	7.867
[illegible]	.9770	8.137	.1229	18.3	.9440	7.861
[illegible]	.9763	8.131	.1230	18.4	.9434	7.856
13.5	.9756	8.125	.1231	18.5	.9428	7.851
13.6	.9749	8.119	.1232	18.6	.9421	7.846
13.7	.9743	8.114	.1232	18.7	.9415	7.841
13.8	.9736	8.108	.1233	18.8	.9409	7.835
13.9	.9729	8.102	.1234	18.9	.9402	7.830
14.0	.9722	8.096	.1235	19.0	.9396	7.825
14.1	.9715	8.091	.1236	19.1	.9390	7.820
14.2	.9709	8.086	.1237	19.2	.9383	7.814
14.3	.9702	8.080	.1238	19.3	.9377	7.809
14.4	.9695	8.074	.1239	19.4	.9371	7.804
14.5	.9688	8.069	.1239	19.5	.9365	7.799
14.6	.9682	8.063	.1240	19.6	.9358	7.793
14.7	.9675	8.058	.1241	19.7	.9352	7.788
14.8	.9669	8.052	.1242	19.8	.9346	7.783
14.9	.9662	8.047	.1243	19.9	.9340	7.778

* Taken from Circular No 57, U. S. Department of Comme
of Standards. U. S. Standard Tables for Petroleum Oils. 1-29

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
20.0	0.9333	7.772	0.1287	26.0	0.8974	7.473	0.1338
20.1	.9327	7.767	.1287	26.1	.8969	7.469	.1339
20.2	.9321	7.762	.1288	26.2	.8963	7.464	.1340
20.3	.9315	7.757	.1289	26.3	.8957	7.459	.1341
20.4	.9309	7.752	.1290	26.4	.8951	7.454	.1342
20.5	.9302	7.747	.1291	26.5	.8946	7.449	.1342
20.6	.9296	7.742	.1292	26.6	.8940	7.445	.1343
20.7	.9290	7.736	.1293	26.7	.8934	7.440	.1344
20.8	.9284	7.731	.1293	26.8	.8929	7.435	.1345
20.9	.9278	7.726	.1294	26.9	.8923	7.430	.1346
21.0	.9272	7.721	.1295	27.0	.8917	7.425	.1347
21.1	.9265	7.716	.1296	27.1	.8912	7.421	.1348
21.2	.9259	7.711	.1297	27.2	.8906	7.416	.1348
21.3	.9253	7.706	.1298	27.3	.8900	7.411	.1349
20.4	.9247	7.701	.1299	27.4	.8895	7.407	.1350
21.5	.9241	7.696	1299	27.5	.8889	7.402	.1351
21.6	.9235	7.690	.1300	27.6	.8883	7.397	.1352
21.7	.9229	7.685	.1301	26.7	.8878	7.393	.1353
21.8	.9223	7.680	.1302	27.8	.8872	7.388	.1354
21.9	.9217	7.675	.1303	27.9	.8866	7.383	.1354
22.0	.9211	7.670	.1304	28.0	.8861	7.378	.1355
22.1	.9204	7.665	.1305	28.1	.8855	7.374	.1356
22.2	.9198	7.660	.1305	28.2	.8850	7.369	.1357
22.3	.9192	7.655	1306	28.3	.8844	7.365	.1358
22.4	.9186	7.650	.1307	28.4	.8838	7.360	.1359
22.5	.9180	7.645	.1308	28.5	.8833	7.355	.1360
22.6	.9174	7.640	.1309	28.6	.8827	7.351	.1360
22.7	.9168	7.635	.1310	28.7	.8822	7.346	.1361
22.8	.9162	7.630	.1311	28.8	.8816	7.341	.1362
22.9	.9156	7.625	.1312	28.9	.8811	7.337	.1363
23.0	.9150	7.620	.1313	29.0	.8805	7.332	.1364
23.1	.9144	7.615	1313	29.1	.8799	7.328	.1365
23.2	.9138	7.610	.1314	29.2	.8794	7.323	.1366
23.3	.9132	7.605	1315	29.3	.8788	7.318	.1366
23.4	.9126	7.600	.1316	29.4	.8783	7.314	.1367
23.5	.9121	7.595	.1317	29.5	.8777	7.309	.1368
23.6	.9115	7.590	.1318	29.6	.8772	7.305	.1369
23.7	.9109	7.585	.1318	29.7	.8766	7.300	.1370
23.8	.9103	7.580	.1319	29.8	.8761	7.295	1371
23.9	.9097	7.575	.1320	29.9	.8755	7.291	.1372
24.0	.9091	7.570	.1321	30.0	.8750	7.286	.1373
24.1	.9085	7.565	.1322	30.1	.8745	7.282	.1373
24.2	.9079	7.561	.1323	30.2	.8739	7.277	.1374
24.3	.9073	7.556	.1323	30.3	.8734	7.273	.1375
24.4	.9067	7.551	.1324	30.4	.8728	7.268	.1376
24.5	.9061	7.546	.1325	30.5	.8723	7.264	.1377
24.6	.9056	7.541	.1326	30.6	.8717	7.259	.1378
24.7	.9050	7.536	.1327	30.7	.8712	7.254	.1379
24.8	.9044	7.531	1328	30.8	.8706	7.249	.1379
24.9	.9038	7.526	.1329	30.9	.8701	7.245	.1380
25.0	.9032	7.522	.1330	31.0	.8696	7.241	.1381
25.1	.9026	7.517	.1330	31.1	.8690	7.236	.1382
25.2	.9021	7.512	.1331	31.2	.8685	7.232	.1383
25.3	.9015	7.507	.1332	31.3	.8679	7.227	.1384
25.4	.9009	7.502	.1333	31.4	.8674	7.223	.1384
25.5	.9003	7.497	.1334	31.5	.8669	7.218	.1385
25.6	.8997	7.493	.1335	31.6	.8663	7.214	.1386
25.7	.8992	7.488	.1335	31.7	.8658	7.210	.1387
25.8	.8986	7.483	.1336	31.8	.8653	7.205	.1388
25.9	.8980	7.478	.1337	31.9	.8647	7.201	.1389

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
32.0	0.8642	7.196	0.1390	38.0	0.8333	6.939	0.1441
32.1	.8637	7.192	.1390	38.1	.8328	6.935	.1442
32.2	.8631	7.187	.1391	38.2	.8323	6.930	.1443
32.3	.8626	7.183	.1392	38.3	.8318	6.926	.1444
32.4	.8621	7.178	.1393	38.4	.8314	6.922	.1445
32.5	.8615	7.173	.1394	38.5	.8309	6.918	.1446
32.6	.8610	7.169	.1395	38.6	.8304	6.914	.1446
32.7	.8605	7.165	.1396	38.7	.8299	6.910	.1447
32.8	.8600	7.161	.1396	38.8	.8294	6.906	.1448
32.9	.8594	7.156	.1397	38.9	.8289	6.902	.1449
33.0	.8589	7.152	.1398	39.0	.8284	6.898	.1450
33.1	.8584	7.147	.1399	39.1	.8279	6.894	.1451
33.2	.8578	7.143	.1400	39.2	.8274	6.889	.1452
33.3	.8573	7.139	.1401	39.3	.8269	6.885	.1452
33.4	.8568	7.134	.1402	39.4	.8264	6.881	.1453
33.5	.8563	7.130	.1403	39.5	.8260	6.877	.1454
33.6	.8557	7.125	.1403	39.6	.8255	6.873	.1455
33.7	.8552	7.121	.1404	39.7	.8250	6.869	.1456
33.8	.8547	7.117	.1405	39.8	.8245	6.865	.1457
33.9	.8542	7.113	.1406	39.9	.8240	6.861	.1458
34.0	.8537	7.108	.1407	40.0	.8235	6.857	.1459
34.1	.8531	7.104	.1408	40.1	.8230	6.853	.1459
34.2	.8526	7.100	.1408	40.2	.8226	6.849	.1460
34.3	.8521	7.095	.1409	40.3	.8221	6.845	.1461
34.4	.8516	7.091	.1410	40.4	.8216	6.841	.1462
34.5	.8511	7.087	.1411	40.5	.8211	6.837	.1463
34.6	.8505	7.082	.1412	40.6	.8206	6.833	.1463
34.7	.8500	7.078	.1413	40.7	.8202	6.829	.1464
34.8	.8495	7.074	.1414	40.8	.8197	6.825	.1465
34.9	.8490	7.069	.1415	40.9	.8192	6.821	.1466
35.0	.8485	7.065	.1415	41.0	.8187	6.817	.1467
35.1	.8480	7.061	.1416	41.1	.8182	6.813	.1468
35.2	.8475	7.057	.1417	41.2	.8178	6.809	.1469
35.3	.8469	7.052	.1418	41.3	.8173	6.805	.1470
35.4	.8464	7.048	.1419	41.4	.8168	6.801	.1470
35.5	.8459	7.044	.1420	41.5	.8163	6.797	.1471
35.6	.8454	7.039	.1421	41.6	.8159	6.793	.1472
35.7	.8449	7.035	.1421	41.7	.8154	6.789	.1473
35.8	.8444	7.031	.1422	41.8	.8149	6.785	.1474
35.9	.8439	7.027	.1423	41.9	.8144	6.781	.1475
36.0	.8434	7.022	.1424	42.0	.8140	6.777	.1476
36.1	.8429	7.018	.1425	42.1	.8135	6.773	.1476
36.2	.8424	7.014	.1426	42.2	.8130	6.769	.1477
36.3	.8419	7.010	.1427	42.3	.8125	6.765	.1478
36.4	.8413	7.006	.1427	42.4	.8121	6.761	.1479
36.5	.8408	7.001	.1428	42.5	.8116	6.758	.1480
36.6	.8403	6.997	.1429	42.6	.8111	6.754	.1481
36.7	.8398	6.993	.1430	42.7	.8107	6.750	.1481
36.8	.8393	6.989	.1431	42.8	.8102	6.746	.1482
36.9	.8388	6.985	.1432	42.9	.8097	6.742	.1483
37.0	.8383	6.980	.1433	43.0	.8092	6.738	.1484
37.1	.8378	6.976	.1433	43.1	.8088	6.734	.1485
37.2	.8373	6.972	.1434	43.2	.8083	6.730	.1486
37.3	.8368	6.968	.1435	43.3	.8078	6.726	.1487
37.4	.8363	6.964	.1436	43.4	.8074	6.722	.1488
37.5	.8358	6.960	.1437	43.5	.8069	6.718	.1489
37.6	.8353	6.955	.1438	43.6	.8065	6.715	.1489
37.7	.8348	6.951	.1439	43.7	.8060	6.711	.1490
37.8	.8343	6.947	.1439	43.8	.8055	6.707	.1491
37.9	.8338	6.943	.1440	43.9	.8051	6.703	.1492

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
44.0	0.8046	6.699	0.1493	50.0	0.7778	6.476	0.1544
44.1	.8041	6.695	.1494	50.1	.7773	6.472	.1545
44.2	.8037	6.691	.1495	50.2	.7769	6.468	.1546
44.3	.8032	6.688	.1495	50.3	.7765	6.465	.1547
44.4	.8028	6.684	.1496	50.4	.7761	6.461	.1548
44.5	.8023	6.680	.1497	50.5	.7756	6.458	.1548
44.6	.8018	6.676	.1498	50.6	.7752	6.454	.1549
44.7	.8014	6.672	.1499	50.7	.7748	6.450	.1550
44.8	.8009	6.668	.1500	50.8	.7743	6.447	.1551
44.9	.8005	6.665	.1500	50.9	.7739	6.443	.1552
45.0	.8000	6.661	.1501	51.0	.7735	6.440	.1553
45.1	.7995	6.657	.1502	51.1	.7731	6.436	.1554
45.2	.7991	6.653	.1503	51.2	.7726	6.432	.1555
45.3	.7986	6.649	.1504	51.3	.7722	6.429	.1555
45.4	.7982	6.646	.1505	51.4	.7718	6.425	.1556
45.5	.7977	6.642	.1506	51.5	.7713	6.421	.1557
45.6	.7973	6.638	.1506	51.6	.7709	6.418	.1558
45.7	.7968	6.634	.1507	51.7	.7705	6.415	.1559
45.8	.7964	6.630	.1508	51.8	.7701	6.411	.1560
45.9	.7959	6.627	.1509	51.9	.7697	6.408	.1561
46.0	.7955	6.623	.1510	52.0	.7692	6.404	.1562
46.1	.7950	6.619	.1511	52.1	.7688	6.401	.1562
46.2	.7946	6.615	.1512	52.2	.7684	6.397	.1563
46.3	.7941	6.612	.1512	52.3	.7680	6.394	.1564
46.4	.7937	6.608	.1513	52.4	.7675	6.390	.1565
46.5	.7932	6.604	.1514	52.5	.7671	6.387	.1566
46.6	.7928	6.600	.1515	52.6	.7667	6.383	.1567
46.7	.7923	6.597	.1516	52.7	.7663	6.380	.1567
46.8	.7919	6.593	.1517	52.8	.7659	6.376	.1568
46.9	.7914	6.589	.1518	52.9	7654	6.373	.1569
47.0	.7910	6.586	.1518	53.0	.7650	6.369	.1570
47.1	.7905	6.582	.1519	53.1	.7646	6.366	.1571
47.2	.7901	6.578	.1520	53.2	.7642	6.362	.1572
47.3	.7896	6.574	.1521	53.3	.7638	6.359	.1573
47.4	.7892	6.571	.1522	53.4	.7634	6.355	.1574
47.5	.7887	6.567	1523	53.5	.7629	6.351	.1574
47.6	.7883	6.563	1524	53.6	.7625	6.348	1575
47.7	.7878	6.560	.1524	53.7	.7621	6.345	.1576
47.8	.7874	6.556	.1525	53.8	.7617	6.341	.1577
47.9	.7870	6.552	.1526	53.9	.7613	6.338	.1578
48.0	.7865	6.548	.1527	54.0	.7609	6.334	1579
48.1	.7861	6.545	.1528	54.1	.7605	6.331	1580
48.2	.7856	6.541	.1529	54.2	.7600	6.327	.1581
48.3	.7852	6.537	.1530	54.3	.7596	6.324	.1581
48.4	.7848	6.534	.1530	54.4	.7592	6.321	.1582
48.5	.7843	6.530	.1531	54.5	.7588	6.317	.1583
48.6	.7839	6.526	.1532	54.6	.7584	6.314	.1584
48.7	.7834	6.523	.1533	54.7	.7580	6.311	.1585
48.8	.7830	6.519	.1534	54.8	.7576	6.307	.1586
48.9	.7826	6.515	.1535	54.9	.7572	6.304	.1586
49.0	.7821	6.511	.1536	55.0	.7568	6.300	.1587
49.1	.7817	6.508	.1537	55.1	.7563	6.296	.1588
49.2	.7812	6.504	.1538	55.2	.7559	6.293	.1589
49.3	.7808	6.501	.1538	55.3	.7555	6.290	.1590
49.4	.7804	6.497	.1539	55.4	.7551	6.287	.1591
49.5	.7799	6.494	.1540	55.5	.7547	6.283	.1592
49.6	.7795	6.490	.1541	55.6	.7543	6.280	.1592
49.7	.7791	6.486	.1542	55.7	.7539	6.276	.1593
49.8	.7786	6.483	.1542	55.8	.7535	6.273	.1594
49.9	.7782	6.479	.1543	55.9	.7531	6.270	.1595

(BUREAU OF STANDARDS MODULUS)
SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
56.0	0.7527	6.266	0.1596	62.0	0.7292	6.070	0.1647
56.1	.7523	6.263	.1597	62.1	.7288	6.067	.1648
56.2	.7519	6.259	.1598	62.2	.7284	6.064	.1649
56.3	.7515	6.256	.1598	62.3	.7280	6.060	.1650
56.4	.7511	6.253	.1599	62.4	.7277	6.057	1651
56.5	.7507	6.249	.1600	62.5	.7273	6.054	.1652
56.6	.7503	6.246	.1601	62.6	.7269	6.051	.1653
56.7	.7499	6.243	.1602	62.7	.7265	6.048	.1653
56.8	.7495	6.240	.1603	62.8	.7261	6.045	.1654
56.9	.7491	6.236	.1604	62.9	.7258	6.042	.1655
57.0	.7487	6.233	.1604	63.0	.7254	6.038	.1656
57.1	.7483	6.229	.1605	63.1	.7250	6.035	.1657
57.2	.7479	6.226	.1606	63.2	.7246	6.032	.1658
57.3	.7475	6.223	.1607	63.3	.7243	6.029	.1659
57.4	.7471	6.219	.1608	63.4	.7239	6.026	.1659
57.5	.7467	6.216	.1609	63.5	.7235	6.023	.1660
57.6	.7463	6.213	.1610	63.6	.7231	6.020	.1661
57.7	.7459	6.209	.1611	63.7	.7228	6.017	.1662
57.8	.7455	6.206	.1611	63.8	.7224	6.014	.1663
57.9	.7451	6.203	.1612	63.9	.7220	6.010	.1664
58.0	.7447	6.199	.1613	64.0	.7216	6.007	.1665
58.1	.7443	6.196	.1614	64.1	.7213	6.004	.1666
58.2	.7439	6.193	.1615	64.2	.7209	6.001	.1666
58.3	.7435	6.190	.1616	64.3	.7205	5.998	.1667
58.4	.7431	6.186	.1617	64.4	.7202	5.995	.1668
58.5	.7427	6.183	.1617	64.5	.7198	5.992	.1669
58.6	.7423	6.180	.1618	64.6	.7194	5.989	.1670
58.7	.7419	6.176	.1619	64.7	.7191	5.986	.1671
58.8	.7415	6.173	.1620	64.8	.7187	5.983	.1671
58.9	.7411	6.170	.1621	64.9	.7183	5.980	.1672
59.0	.7407	6.166	.1622	65.0	.7179	5.976	.1673
59.1	.7403	6.163	.1623	65.1	.7176	5.973	.1674
59.2	.7400	6.160	.1623	65.2	.7172	5.970	.1675
59.3	.7396	6.157	.1624	65.3	.7168	5.967	.1676
59.4	.7392	6.154	.1625	65.4	.7165	5.964	.1677
59.5	.7388	6.150	.1626	65.5	.7161	5.961	.1678
59.6	.7384	6.147	.1627	65.6	.7157	5.958	.1678
59.7	.7380	6.144	.1628	65.7	.7154	5.955	.1679
59.8	.7376	6.141	.1628	65.8	.7150	5.952	.1680
59.9	.7372	6.137	.1629	65.9	.7147	5.949	.1681
60.0	.7368	6.134	.1630	66.0	.7143	5.946	.1682
60.1	.7365	6.131	.1631	66.1	.7139	5.943	.1683
60.2	.7361	6.128	.1632	66.2	.7136	5.940	.1684
60.3	.7357	6.124	.1633	66.3	.7132	5.937	.1684
60.4	.7353	6.121	.1634	66.4	.7128	5.934	.1685
60.5	.7349	6.118	.1635	66.5	.7125	5.931	.1686
60.6	.7345	6.115	.1635	66.6	.7121	5.928	.1687
60.7	.7341	6.112	.1636	66.7	.7117	5.925	.1688
60.8	.7338	6.108	.1637	66.8	.7114	5.922	.1689
60.9	.7334	6.105	.1638	66.9	.7110	5.919	.1689
61.0	.7330	6.102	.1639	67.0	.7107	5.916	.1690
61.1	.7326	6.099	.1640	67.1	.7103	5.913	.1691
61.2	.7322	6.096	.1640	67.2	.7099	5.910	.1692
61.3	.7318	6.093	.1641	67.3	.7096	5.907	.1693
61.4	.7315	6.090	.1642	67.4	.7092	5.904	.1694
61.5	.7311	6.086	.1643	67.5	.7089	5.901	.1695
61.6	.7307	6.083	.1644	67.6	.7085	5.898	.1695
61.7	.7303	6.080	.1645	67.7	.7081	5.895	.1696
61.8	.7299	6.077	.1646	67.8	.7078	5.892	.1697
61.9	.7295	6.073	.1647	67.9	.7074	5.889	.1698

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
68.0	0.7071	5.886	0.1699	74.0	0.6863	5.712	0.1751
68.1	.7067	5.883	.1700	74.1	.6859	5.710	.1751
68.2	.7064	5.880	.1701	74.2	.6856	5.707	.1752
68.3	.7060	5.877	.1702	74.3	.6853	5.704	.1753
68.4	.7056	5.874	.1702	74.4	.6849	5.701	.1754
68.5	.7053	5.871	.1703	74.5	.6846	5.698	.1755
68.6	.7049	5.868	.1704	74.6	.6843	5.696	.1756
68.7	.7046	5.865	.1705	74.7	.6839	5.693	.1757
68.8	.7042	5.862	.1706	74.8	.6836	5.690	.1757
68.9	.7039	5.859	.1707	74.9	.6833	5.687	.1758
69.0	.7035	5.856	.1708	75.0	.6829	5.685	.1759
69.1	.7032	5.853	.1709	75.1	.6826	5.682	.1760
69.2	.7028	5.850	.1709	75.2	.6823	5.679	.1761
69.3	.7025	5.848	.1710	75.3	.6819	5.676	.1762
69.4	.7021	5.845	.1711	75.4	.6816	5.673	.1763
69.5	.7018	5.842	.1712	75.5	.6813	5.671	.1763
69.6	.7014	5.839	.1713	75.6	.6809	5.668	.1764
69.7	.7011	5.836	.1714	75.7	.6806	5.665	.1765
69.8	.7007	5.833	.1714	75.8	.6803	5.662	.1766
69.9	.7004	5.830	.1715	75.9	.6799	5.660	.1767
70.0	.7000	5.827	.1716	76.0	.6796	5.657	.1768
70.1	.6997	5.824	.1717	76.1	.6793	5.654	.1769
70.2	.6993	5.821	.1718	76.2	.6790	5.652	.1769
70.3	.6990	5.818	.1719	76.3	.6786	5.649	.1770
70.4	.6986	5.815	.1720	76.4	.6783	5.646	.1771
70.5	.6983	5.812	.1721	76.5	.6780	5.643	.1772
70.6	.6979	5.810	.1721	76.6	.6776	5.640	.1773
70.7	.6976	5.807	.1722	76.7	.6773	5.638	.1774
70.8	.6972	5.804	.1723	76.8	.6770	5.635	.1775
70.9	6969	5.801	.1724	76.9	.6767	5.632	.1776
71.0	.6965	5.798	.1725	77.0	.6763	5.629	1776
71.1	.6962	5.795	.1726	77.1	.6760	5.627	.1777
71.2	.6958	5.792	.1727	77.2	.6757	5.624	.1778
71.3	.6955	5.789	.1727	77.3	.6753	5.621	.1779
71.4	.6951	5.786	.1728	77.4	.6750	5.618	.1780
71.5	.6948	5.784	.1729	77.5	.6747	5.616	.1781
71.6	.6944	5.781	.1730	77.6	.6744	5.613	.1782
71.7	.6941	5.778	.1731	77.7	.6740	5.610	.1783
71.8	.6938	5.775	.1732	77.8	.6737	5.608	.1783
71.9	.6934	5.772	.1733	77.9	.6734	5.605	.1784
72.0	.6931	5.769	.1733	78.0	.6731	5.602	.1785
72.1	.6927	5.766	.1734	78.1	.6728	5.600	.1786
72.2	.6924	5.763	.1735	78.2	.6724	5.597	.1787
72.3	.6920	5.760	.1736	78.3	.6721	5.594	.1788
72.4	.6917	5.758	.1737	78.4	.6718	5.592	.1788
72.5	.6914	5.755	.1738	78.5	.6715	5.589	.1789
72.6	.6910	5.752	.1739	78.6	.6711	5.586	.1790
72.7	.6907	5.749	.1739	78.7	.6708	5.584	.1791
72.8	.6903	5.746	.1740	78.8	.6705	5.581	.1792
72.9	.6900	5.744	.1741	78.9	.6702	5.578	.1793
73.0	.6897	5.741	.1742	79.0	.6689	5.576	.1793
73.1	.6893	5.738	.1743	79.1	.6695	5.573	.1794
73.2	.6890	5.735	.1744	79.2	.6692	5.570	.1795
73.3	.6886	5.732	.1745	79.3	.6689	5.568	.1796
73.4	.6883	5.729	.1746	79.4	.6686	5.565	.1797
73.5	.6880	5.727	.1746	79.5	.6683	5.562	.1798
73.6	.6876	5.724	.1747	79.6	.6679	5.560	.1799
73.7	.6873	5.721	.1748	79.7	.6676	5.557	.1800
73.8	.6869	5.718	.1749	79.8	.6673	5.554	.1801
73.9	.6866	5.715	.1750	79.9	.6670	5.552	[illegible]

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
80.0	0.6667	5.549	0.1802	86.0	0.6482	5.395	0.1854
80.1	.6663	5.546	1803	86.1	.6479	5.392	.1855
80.2	.6660	5.543	1804	86.2	.6476	5.390	.1855
80.3	.6657	5.541	1805	86.3	.6473	5.387	.1856
80.4	.6654	5.538	1806	86.4	.6470	5.385	1857
80.5	.6651	5.536	1806	86.5	.6467	5.382	.1858
80.6	6648	5.533	.1807	86.6	.6464	5.380	.1859
80.7	.6645	5.531	.1808	86.7	.6461	5.377	.1860
80.8	.6641	5.528	.1809	86.8	.6458	5.375	.1860
80.9	6638	5.525	.1810	86.9	.6455	5.372	1861
81.0	6635	5.522	.1811	87.0	.6452	5.370	.1862
81.1	.6632	5.520	.1812	87.1	.6449	5.367	.1863
81.2	.6629	5.517	.1813	87.2	.6446	5.365	.1864
81.3	.6626	5.515	.1813	87.3	.6443	5.362	.1865
80.4	.6623	5.512	.1814	87.4	6440	5.360	.1866
81.5	.6619	5.510	.1815	87.5	.6437	5.357	.1867
81.6	.6616	5.507	.1816	87.6	.6434	5.355	.1867
81.7	.6613	5.504	.1817	87.7	.6431	5.352	.1868
81.8	.6610	5.502	.1818	87.8	.6428	5.350	.1869
81.9	.6607	5.499	1819	87.9	.6425	5.347	.1870
82.0	.6604	5.497	.1819	88.0	.6422	5.345	.1871
82.1	.6601	5.494	.1820	88.1	.6419	5.343	.1872
82.2	.6598	5.491	.1821	88.2	.6416	5.340	.1873
82.3	.6594	5.589	.1822	88.3	.6413	5.338	.1873
82.4	.6591	5.486	.1823	88.4	.6410	5.335	.1874
82.5	.6588	5.484	.1823	88.5	.6407	5.333	.1875
82.6	.6585	5.481	.1824	88.6	.6404	5.330	.1876
82.7	.6582	5.478	.1825	88.7	.6401	5.328	.1877
82.8	.6579	5.476	.1826	88.8	.6399	5.325	.1878
82.9	.6576	5.473	.1827	88.9	.6396	5.323	.1879
83.0	.6573	5.471	.1828	89.0	.6393	5.320	.1880
83.1	.6570	5.468	.1829	89.1	.6390	5.318	.1880
83.2	.6567	5.466	.1829	89.2	.6387	5.316	.1881
83.3	.6564	5.463	.1830	89.3	.6384	5.313	.1882
83.4	.6560	5.460	.1831	89.4	.6581	5.311	1883
83.5	.6557	5.458	.1832	89.5	.6378	5.308	.1884
83.6	.6554	5.455	.1833	89.6	.6375	5.306	.1885
83.7	.6551	5.553	.1834	89.7	.6372	5.304	.1885
83.8	.6548	5.450	.1835	89.8	.6369	5.301	.1886
83.9	.6545	5.448	.1836	89.9	6367	5.299	1887
84.0	.6542	5.445	.1837	90.0	.6364	5.296	.1888
84.1	.6539	5.443	.1837	90.1	.6361	5.294	.1889
84.2	.6536	5.440	.1838	90.2	.6358	5.291	.1890
84.3	.6533	5.437	.1839	90.3	.6355	5.289	.1891
84.4	.6530	5.435	.1840	90.4	.6352	5.286	.1892
84.5	.6527	5.432	.1841	90.5	.6349	5.284	.1893
84.6	.6524	5.430	.1842	90.6	.6346	5.281	.1894
84.7	.6521	5.427	.1843	90.7	.6343	5.279	.1894
84.8	.6518	5.425	.1843	90.8	.6341	5.277	.1895
84.9	.6515	5.422	1844	90.9	.6338	5.275	1896
85.0	.6512	5.420	.1845	91.0	.6335	5.272	.1897
85.1	.6509	5.417	.1846	91.1	.6332	5.270	.1898
85.2	.6506	5.415	.1847	91.2	.6329	5.267	.1899
85.3	.6503	5.412	.1848	91.3	.6326	5.265	.1899
85.4	.6500	5.410	.1848	91.4	.6323	5.263	.1900
85.5	.6497	5.407	.1849	91.5	.6321	5.261	.1901
85.6	.6494	5.405	.1850	91.6	.6318	5.258	.1902
85.7	.6490	5.402	.1851	91.7	.6315	5.256	.1903
85.8	.6487	5.400	.1852	91.8	.6312	5.253	.1904
85.9	.6484	5.397	.1853	91.9	.6309	5.251	.1904

(BUREAU OF STANDARDS MODULUS) SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS DEGREES BAUMÉ DESIGNATED (Continued)

Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound	Degrees Baumé	Specific gravity at 60°/60° F	Pounds per gallon	Gallons per pound
92.0	0.6306	5.248	0.1905	96.0	0.6195	5.155	0.1940
92.1	.6303	5.246	.1906	96.1	.6192	5.153	.1941
92.2	.6301	5.244	.1907	96.1	.6189	5.150	.1942
92.3	.6298	5.241	1908	96.3	.6186	5.148	.1943
92.4	.6295	5.239	.1909	96.4	.6184	5.146	.1943
92.5	.6292	5.236	.1910	96.5	.6181	5.144	.1944
92.6	.6289	5.234	.1911	96.6	.6178	5.142	.1945
92.7	.6286	5.232	.1911	96.7	.6176	5.140	.1946
92.8	.6284	5.230	.1912	96.8	.6173	5.137	.1947
92.9	.6281	5.227	.1913	96.9	.6170	5.135	.1948
93.0	.6278	5.225	.1914	97.0	.6167	5.132	.1949
93.1	.6275	5.222	.1915	97.1	.6165	5.130	.1949
93.2	.6272	5.220	.1916	97.2	.6162	5.128	.1950
93.3	.6270	5.218	.1916	97.3	.6159	5.126	.1951
93.4	.6267	5.216	.1917	97.4	.6157	5.124	.1952
93.5	.6264	5.213	.1918	97.5	.6154	5.121	.1953
93.6	.6261	5.210	.1919	97.6	.6151	5.119	.1954
93.7	.6258	5.208	.1920	97.7	.6148	5.116	.1955
93.8	.6256	5.206	.1921	97.8	.6146	5.114	.1955
93.9	.6253	5.204	.1922	97.9	.6143	5.112	.1956
94.0	.6250	5.201	.1923	98.0	.6140	5.110	.1957
94.1	.6247	5.199	.1924	98.1	.6138	5.108	.1958
94.2	.6244	5.196	.1925	98.2	.6135	5.106	.1958
94.3	.6242	5.194	.1925	98.3	.6132	5.103	.1960
94.4	.6239	5.192	.1926	98.4	.6130	5.101	.1960
94.5	.6236	5.190	.1927	98.5	.6127	5.099	.1961
94.6	.6233	5.187	.1928	98.6	.6124	5.096	.1962
94.7	.6231	5.185	.1929	98.7	.6122	5.094	.1963
94.8	.6228	5.183	.1929	98.8	.6119	5.092	.1964
94.9	.6225	5.180	.1930	98.9	.6116	5.090	.1965
95.0	.6222	5.178	.1931	99.0	.6114	5.088	.1966
95.1	.6219	5.176	.1932	99.1	.6111	5.085	.1967
95.2	.6217	5.174	.1933	99.2	.6108	5.083	.1967
95.3	.6214	5.171	.1934	99.3	.6106	5.081	.1968
95.4	.6211	5.169	.1935	99.4	.6103	5.079	.1969
				99.5	.6100	5.076	.1970
95.5	.6208	5.166	.1936	99.6	.6098	5.074	.1971
95.6	.6206	5.164	.1936	99.7	.6095	5.072	.1972
95.7	.6203	5.162	.1937	99.8	.6092	5.070	.1972
95.8	.6200	5.160	.1938	99.9	.6090	5.068	.1973
95.9	.6197	5.157	.1939	100.0	.6087	5.066	.1974

(BUREAU OF STANDARDS MODULUS)

* DEGREES BAUMÉ, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS SPECIFIC GRAVITIES DESIGNATED

Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound	Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound
0.600	103.33	4.993	0.2003	0.650	85.38	5.410	0.1848
.601	102.94	5.001	.1999	.651	85.05	5.418	.1846
.602	102.56	5.010	.1996	.652	84.72	5.426	.1843
.603	102.17	5.018	.1993	.653	84.40	5.435	.1840
.604	101.79	5.026	.1990	.654	84.07	5.443	.1837
.605	101.40	5.035	.1986	.655	83.74	5.452	.1834
.606	101.02	5.043	.1983	.656	83.42	5.460	.1832
.607	100.64	5.051	.1980	.657	83.09	5.468	.1829
.608	100.26	5.060	.1976	.658	82.77	5.476	.1826
.609	99.88	5.068	.1973	.659	82.44	5.485	.1823
.610	99.51	5.076	.1970	.660	82.12	5.493	.1820
.611	99.13	5.084	.1967	.661	81.80	5.502	.1818
.612	98.76	5.093	.1963	.662	81.48	5.510	.1815
.613	98.38	5.101	.1960	.663	81.16	5.518	.1812
.614	98.01	5.110	.1957	.664	80.84	5.526	.1810
.615	97.64	5.118	.1954	.665	80.53	5.535	.1807
.616	97.27	5.126	.1951	.666	80.21	5.543	.1804
.617	96.90	5.135	.1948	.667	79.90	5.552	.1801
.618	96.54	5.143	.1944	.668	79.58	5.560	.1799
.619	96.17	5.151	.1941	.669	79.27	5.568	.1796
.620	95.81	5.160	.1938	.670	78.96	5.577	.1793
.621	95.44	5.168	.1935	.671	78.64	5.585	.1790
.622	95.08	5.176	.1932	.672	78.33	5.593	.1788
.623	94.72	5.185	.1929	.673	78.02	5.602	.1785
.624	94.36	5.193	.1926	.674	77.72	5.610	.1782
.625	94.00	5.201	.1923	.675	77.41	5.618	.1780
.626	93.64	5.210	.1920	.676	77.10	5.627	.1777
.627	93.28	5.218	.1916	.677	76.80	5.635	.1775
.628	92.93	5.226	.1913	.678	76.49	5.643	.1772
.629	92.58	5.235	.1910	.679	76.19	5.652	.1769
.630	92.22	5.243	.1907	.680	75.88	5.660	.1767
.631	91.87	5.251	.1904	.681	75.58	5.668	.1764
.632	91.52	5.260	.1901	.682	75.28	5.677	.1762
.633	91.17	5.268	.1898	.683	74.98	5.685	.1759
.634	90.82	5.276	.1895	.684	74.68	5.693	.1756
.635	90.47	5.285	.1892	.685	74.38	5.702	.1754
.636	90.13	5.293	.1889	.686	74.08	5.710	.1751
.637	89.78	5.301	.1886	.687	73.78	5.718	.1749
.638	89.44	5.310	.1883	.688	73.49	5.727	.1746
.639	89.09	5.318	.1880	.689	73.19	5.735	.1744
.640	88.75	5.326	.1877	.690	72.90	5.743	.1741
.641	88.41	5.335	.1874	.691	72.60	5.752	.1739
.642	88.07	5.343	.1872	.692	72.31	5.760	.1736
.643	87.73	5.351	.1869	.693	72.02	5.768	.1734
.644	87.39	5.360	.1866	.694	71.73	5.777	.1731
.645	87.05	5.368	.1863	.695	71.44	5.785	.1729
.646	86.72	5.376	.1860	.696	71.15	5.793	.1726
.647	86.38	5.385	.1857	.697	70.86	5.802	.1724
.648	86.05	5.393	.1854	.698	70.57	5.810	.1721
.649	85.72	5.402	.1851	.699	70.29	5.818	.1719

* Taken from Circular No. 57, U. S. Bureau of Standards, "United States Standard Table for Petroleum Oils."

(BUREAU OF STANDARDS MODULUS) DEGREES BAUMÉ, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS SPECIFIC GRAVITIES DESIGNATED (Continued)

Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound	Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound
0.700	70.00	5.827	0.1716	0.750	56.67	6.244	0.1602
.701	69.72	5.835	.1714	.751	56.42	6.252	.1600
.702	69.43	5.843	.1711	.752	56.17	6.260	.1597
.703	69.15	5.852	.1709	.753	55.92	6.269	.1595
.704	68.86	5.860	.1706	.754	55.68	6.277	.1593
.705	68.58	5.868	.1704	.755	55.43	6.285	.1591
.706	68.30	5.877	.1702	.756	55.18	6.294	.1589
.707	68.02	5.885	.1699	.757	54.94	6.302	.1587
.708	67.74	5.894	.1697	.758	54.70	6.310	.1585
.709	67.46	5.902	.1694	.759	54.45	6.319	.1583
.710	67.18	5.910	.1692	.760	54.21	6.327	.1580
.711	66.91	5.918	.1690	.761	53.97	6.335	.1578
.712	66.63	5.927	.1687	.762	53.73	6.344	.1576
.713	66.35	5.935	.1685	.763	53.49	6.352	.1574
.714	66.08	5.944	.1682	.764	53.25	6.360	.1572
.715	65.80	5.952	.1680	.765	53.01	6.369	.1570
.716	65.53	5.960	.1678	.766	52.77	6.377	.1568
.717	65.26	5.968	.1676	.767	52.53	6.386	.1566
.718	64.99	5.977	.1673	.768	52.29	6.394	.1564
.719	64.72	5.985	.1671	.769	52.06	6.402	.1562
.720	64.44	5.994	.1668	.770	51.82	6.410	.1560
.721	64.18	6.002	.1666	.771	51.58	6.419	.1558
.722	63.91	6.010	.1664	.772	51.35	6.427	.1556
.723	63.64	6.018	.1662	.773	51.11	6.436	.1554
.724	63.37	6.027	.1659	.774	50.88	6.444	.1552
.725	63.10	6.035	.1657	.775	50.64	6.452	.1550
.726	62.84	6.044	.1655	.776	50.41	6.460	.1548
.727	62.57	6.052	.1652	.777	50.18	6.469	.1546
.728	62.31	6.060	.1650	.778	49.95	6.477	.1544
.729	62.04	6.068	.1648	.779	49.72	6.486	.1542
.730	61.78	6.077	.1646	.780	49.49	6.494	.1540
.731	61.52	6.085	.1643	.781	49.26	6.502	.1538
.732	61.26	6.094	.1641	.782	49.03	6.510	.1536
.733	61.00	6.102	.1639	.783	48.80	6.519	.1534
.734	60.74	6.110	.1637	784	48.57	6.527	.1532
.735	60.48	6.119	.1634	785	48.34	6.536	.1530
.736	60.22	6.127	.1632	.786	48.12	6.544	.1528
.737	59.96	6.135	.1630	.787	47.89	6.552	.1526
.738	59.70	6.144	.1628	.788	47.66	6.560	.1524
.739	59.44	6.152	.1626	.789	47.44	6.569	.1522
.740	59.19	6.160	.1623	.790	47.22	6.577	.1520
.741	58.93	6.169	.1621	.791	46.99	6.586	.1518
.742	58.68	6.177	.1619	.792	46.77	6.594	.1517
.743	58.42	6.185	.1617	.793	46.54	6.602	.1515
.744	58.17	6.194	.1615	.794	46.32	6.611	.1513
.745	57.92	6.202	.1612	.795	46.10	6.619	.1511
.746	57.67	6.210	.1610	.796	45.88	6.627	.1509
.747	57.42	6.219	.1608	.797	45.66	6.636	.1507
.748	57.17	6.227	.1606	.798	45.44	6.644	.1505
.749	56.92	6.235	.1604	.799	45.22	6.652	1503

(BUREAU OF STANDARDS MODULUS) DEGREES BAUMÉ, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS SPECIFIC GRAVITIES DESIGNATED (Continued)

Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound	Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound
0.800	45.00	6.661	0.1501	0.850	34.71	7.078	0.1413
.801	44.78	6.669	.1500	.851	34.51	7.086	.1411
.802	44.56	6.677	.1498	.852	34.32	7.094	.1410
.803	44.35	6.686	.1496	.853	34.13	7.103	.1408
.804	44.13	6.694	.1494	.854	33.93	7.111	.1406
.805	43.91	6.702	.1492	.855	33.74	7.119	.1405
.806	43.70	6.711	.1490	.856	33.55	7.128	.1403
.807	43.48	6.719	.1488	.857	33.36	7.136	.1401
.808	43.27	6.727	.1486	.858	33.17	7.144	.1400
.809	43.05	6.736	.1485	.859	32.98	7.153	.1398
.810	42.84	6.744	.1483	.860	32.79	7.161	.1396
.811	42.63	6.752	.1481	.861	32.60	7.169	.1395
.812	42.41	6.761	.1479	.862	32.41	7.178	.1393
.813	42.20	6.769	.1477	.863	32.22	7.186	.1392
.814	41.99	6.777	.1476	.864	32.04	7.194	.1390
.815	41.78	6.786	.1474	.865	31.85	7.203	.1388
.816	41.57	6.794	.1472	.866	31.66	7.211	.1387
.817	41.36	6.802	.1470	.867	31.48	7.219	.1385
818	41.15	6.811	.1468	.868	31.29	7.228	.1384
.819	40.94	6.819	.1466	.869	31.10	7.236	.1382
.820	40.73	6.827	.1465	.870	30.92	7.244	.1380
.821	40.52	6.836	.1463	.871	30.74	7.253	.1379
.822	40.32	6.844	.1461	.872	30.55	7.261	.1377
.823	40.11	6.852	.1459	.873	30.37	7.269	.1376
.824	39.90	6.861	.1458	.874	30.18	7.278	.1374
.825	39.70	6.869	.1456	.875	30.00	7.286	.1372
.826	39.49	6.877	.1454	.876	29.82	7.294	.1371
.827	39.29	6.886	.1452	.877	29.64	7.303	.1369
.828	39.08	6.894	.1450	.878	29.45	7.311	.1368
.829	38.88	6.902	.1449	.879	29.27	7.319	.1366
.830	38.68	6.911	.1447	.880	29.09	7.328	.1365
.831	38.47	6.919	.1445	.881	28.91	7.336	.1363
.832	38.27	6.927	.1444	.882	28.73	7.344	.1362
.833	38.07	6.936	.1442	.883	28.55	7.353	.1360
.834	37.87	6.944	.1440	.884	28.37	7.361	.1358
.835	37.66	6.952	.1438	.885	28.19	7.369	.1357
.836	37.46	6.961	.1437	.886	28.01	7.378	.1355
.837	37.26	6.969	.1435	.887	27.84	7.386	.1354
.838	37.06	6.978	.1433	.888	27.66	7.394	.1352
.839	36.87	6.986	.1432	.889	27.48	7.403	.1351
.840	36.67	6.994	.1430	.890	27.30	7.411	.1349
.841	36.47	7.003	.1428	.891	27.13	7.419	.1348
.842	36.27	7.011	.1426	.892	26.95	7.428	.1346
.843	36.07	7.019	.1425	.893	26.78	7.436	.1345
.844	35.88	7.028	.1423	.894	26.60	7.444	.1343
.845	35.68	7.036	.1421	.895	26.42	7.453	.1342
.846	35.48	7.044	.1420	.896	26.25	7.461	.1340
.847	35.29	7.052	.1481	.897	26.08	7.469	.1339
.848	35.09	7.061	.1416	.898	25.90	7.478	.1337
.849	34.90	7.069	.1415	.899	25.73	7.486	.1336

(BUREAU OF STANDARDS MODULUS)
DEGREES BAUMÉ, POUNDS PER GALLON, AND GALLONS PER POUND, CORRESPONDING TO THE VARIOUS SPECIFIC GRAVITIES DESIGNATED (Continued)

Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound	Specific gravity at 60°/60° F	Degrees Baumé	Pounds per gallon	Gallons per pound
0.900	25.56	7.494	0.1334	0.950	17.37	7.911	0.1264
.901	25.38	7.503	.1333	.951	17.21	7.920	.1263
.902	25.21	7.511	.1331	.952	17.06	7.928	.1261
.903	25.04	7.519	.1330	.953	16.90	7.937	.1260
.904	24.87	7.528	.1328	.954	16.75	7.945	.1259
.905	24.70	7.536	.1327	.955	16.60	7.953	.1257
.906	24.52	7.544	.1326	.956	16.44	7.962	.1256
.907	24.36	7.553	.1324	.957	16.29	7.970	.1255
.908	24.18	7.561	.1323	.958	16.14	7.978	.1253
.909	24.02	7.569	.1321	.959	15.98	7.987	.1252
.910	23.85	7.578	.1320	.960	15.83	7.995	.1251
.911	23.68	7.586	.1318	.961	15.68	8.003	.1250
.912	23.51	7.594	.1317	.962	15.53	8.012	.1248
.913	23.34	7.603	.1315	.963	15.38	8.020	.1247
.914	23.17	7.611	.1314	.964	15.23	8.028	.1246
.915	23.00	7.620	.1312	.965	15.08	8.036	.1244
.916	22.84	7.628	.1311	.966	14.93	8.045	.1243
.917	22.67	7.636	.1310	.967	14.78	8.053	.1242
.918	22.51	7.645	.1308	.968	14.63	8.062	.1240
.919	22.34	7.653	.1307	.969	14.48	8.070	.1239
.920	22.17	7.661	.1305	.970	14.33	8.078	.1238
.921	22.01	7.670	.1304	.971	14.18	8.087	.1237
.922	21.84	7.678	.1302	.972	14.03	8.095	.1235
.923	21.68	7.686	.1301	.973	13.88	8.103	.1234
.924	21.52	7.695	.1300	.974	13.74	8.112	.1233
.925	21.35	7.703	.1298	.975	13.59	8.120	.1232
.926	21.19	7.711	.1297	.976	13.44	8.128	.1230
.927	21.02	7.720	.1295	.977	13.30	8.137	.1229
.928	20.86	7.728	.1294	.978	13.15	8.145	.1228
.929	20.70	7.736	.1293	.979	13.00	8.153	.1227
.930	20.54	7.745	.1291	.980	12.86	8.162	.1225
.931	20.38	7.753	.1290	.981	12.71	8.170	.1224
.932	20.22	7.761	.1288	.982	12.57	8.178	.1223
.933	20.05	7.770	.1287	.983	12.42	8.187	.1221
.934	19.89	7.778	.1286	.984	12.28	8.195	.1220
.935	19.73	7.786	.1284	.985	12.13	8.203	.1219
.936	19.57	7.795	.1283	.986	11.99	8.212	.1218
.937	19.41	7.803	.1282	.987	11.84	8.220	.1217
.938	19.25	7.811	.1280	.988	11.70	8.228	.1215
.939	19.10	7.820	.1279	.989	11.56	8.237	.1214
.940	18.94	7.828	.1278	.990	11.41	8.245	.1213
.941	18.78	7.836	.1276	.991	11.27	8.253	.1212
.942	18.62	7.845	.1275	.992	11.13	8.262	.1210
.943	18.46	7.853	.1273	.993	10.99	8.270	.1209
.944	18.30	7.861	.1272	.994	10.84	8.278	.1208
.945	18.15	7.870	.1271	.995	10.70	8.287	.1207
.946	17.99	7.878	.1269	.996	10.56	8.295	.1206
.947	17.84	7.886	.1268	.997	10.42	8.303	.1204
.948	17.68	7.895	.1267	.998	10.28	8.312	.1203
.949	17.52	7.903	.1265	.999	10.14	8.320	.1202
				1.000	10.00	8.328	.1201

COMPARATIVE TABLE (OIL TRADE)

WEIGHT AND GRAVITY (Liquids Lighter Than Water at 60° F.)

Degrees Baumé; Corresponding Specific Gravity; Weight per gallon.

Based on Modulus $\frac{141.5}{131.5+B}$=Specific Gravity at 60° F.

Baumé Gravity	Specific Gravity	Weight per gallon	Baumé Gravity	Specific Gravity	Weight per gallon	Baumé Gravity	Specific Gravity	Weight per gallon
10	1.0000	8.331	28.5	.8844	7.368	47	.7927	6.604
10.5	.9965	8.302	29	.8816	7.345	47.5	.7905	6.586
11	.9930	8.273	29.5	.8789	7.322	48	.7883	6.567
11.5	.9895	8.244	30	.8762	7.300	48.5	.7861	6.549
12	.9861	8.215	30.5	.8735	7.277	49	.7839	6.531
12.5	.9826	8.186	31	.8708	7.255	49.5	.7818	6.513
13	.9792	8.158	31.5	.8687	7.237	50	.7796	6.495
13.5	.9759	8.130	32	.8654	7.209	50.5	.7775	6.477
14	.9725	8.102	32.5	.8628	7.188	51	.7753	6.459
14.5	.9692	8.074	33	.8602	7.166	51.5	.7732	6.442
15	.9659	8.047	33.5	.8576	7.144	52	.7711	6.424
15.5	.9626	8.019	34	.8550	7.123	52.5	.7690	6.407
16	.9593	7.992	34.5	.8524	7.096	53	.7669	6.389
16.5	.9561	7.965	35	.8498	7.079	53.5	.7643	6.367
17	.9529	7.939	35.5	.8473	7.059	54	.7628	6.355
17.5	.9497	7.912	36	.8448	7.038	54.5	.7608	6.338
18	.9465	7.885	36.5	.8423	7.017	55	.7588	6.322
18.5	.9433	7.859	37	.8398	6.996	55.5	.7567	6.304
19	.9402	7.833	37.5	.8373	6.976	56	.7547	6.287
19.5	.9371	7.807	38	.8348	6.955	56.5	.7525	6.269
20	.9340	7.781	38.5	.8324	6.934	57	.7507	6.254
20.5	.9309	7.755	39	.8300	6.915	57.5	.7487	6.239
21	.9279	7.730	39.5	.8275	6.894	58	.7467	6.221
21.5	.9248	7.704	40	.8251	6.874	58.5	.7447	6.204
22	.9218	7.680	40.5	.8227	6.853	59	.7428	6.187
22.5	.9190	7.656	41	.8203	6.834	59.5	.7408	6.172
23	.9159	7.630	41.5	.8179	6.814	60	.7389	6.156
23.5	.9129	7.605	42	.8156	6.795	60.5	.7370	6.140
24	.9100	7.581	42.5	.8132	6.775	61	.7351	6.124
24.5	.9071	7.557	43	.8109	6.756	61.5	.7332	6.108
25	.9042	7.533	43.5	.8086	6.736	62	.7313	6.092
25.5	.9013	7.509	44	.8063	6.717	62.5	.7294	6.077
26	.8984	7.485	44.5	.8040	6.698	63	.7275	6.061
26.5	.8956	7.461	45	.8017	6.679	63.5	.7256	6.045
27	.8927	7.437	45.5	.7994	6.660	64	.7238	6.030
27.5	.8900	7.415	46	.7972	6.641	64.5	.7219	6.014
28	.8871	7.390	46.5	.7949	6.622	65	.7201	5.999

BAUMÉ TEMPERATURE CORRECTION.—When using the Baumé hydrometer, it is customary to deduct 1 from the hydrometer reading for every 10 degrees Fahrenheit that the temperature of the oil is above 60° Fahr., and to add 1 for every 10 degrees that the temperature is below 60° Fahr. As an example, if the hydrometer reads a gravity of 30° Bé at 70° Fahr., the corrected reading would be 29° Bé. This correction gives only an approximate result and is suitable for field work only. For accurate corrections, refer to table on page 284, which gives the exact gravities at various temperatures.

BAUMÉ GRAVITY—TEMPERATURE CORRECTIONS

TEMPERATURE CORRECTIONS TO READINGS OF BAUMÉ HYDROMETERS IN AMERICAN PETROLEUM OILS AT VARIOUS TEMPERATURES

(Standard at 60° F.; modulus 140)

Observed Temperature °F.	Observed degrees Baumé							
	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
	Add to observed degrees Baumé							
30	1.7	2.0	2.4	3.0	3.7	4.3	5.0	5.7
32	1.6	1.9	2.3	2.8	3.4	4.0	4.7	5.3
34	1.5	1.8	2.1	2.6	3.1	3.7	4.3	4.9
36	1.4	1.6	2.0	2.4	2.9	3.4	4.0	4.6
38	1.3	1.5	1.8	2.2	2.6	3.1	3.6	4.2
40	1.2	1.4	1.6	2.0	2.4	2.8	3.2	3.8
42	1.1	1.2	1.5	1.8	2.2	2.5	2.9	3.4
44	.9	1.1	1.3	1.6	2.0	2.2	2.6	3.0
46	.8	.9	1.1	1.4	1.7	1.9	2.3	2.7
48	.7	.8	.9	1.2	1.4	1.6	2.0	2.3
50	.6	.7	.8	1.0	1.2	1.4	1.6	1.9
52	.5	.6	.7	.8	1.0	1.1	1.3	1.5
54	.3	.4	.5	.6	.8	.9	1.0	1.1
56	.2	.3	.3	.4	.5	.6	.6	.7
58	.1	.1	.1	.2	.3	.3	.3	.4
	Subtract from observed degrees Baumé							
60	.0	.0	.0	.0	.0	.0	.0	.0
62	.1	.1	.1	.2	.2	.3	.3	.4
64	.2	.3	.3	.4	.4	.6	.6	.7
66	.3	.4	.5	.6	.7	.8	.9	1.0
68	.5	.6	.6	.7	.9	1.1	1.3	1.4
70	.6	.7	.8	.9	1.1	1.4	1.6	1.7
72	.7	.8	.9	1.1	1.3	1.6	1.9	2.1
74	.8	.9	1.1	1.3	1.6	1.8	2.2	2.5
76	.9	1.1	1.3	1.5	1.8	2.1	2.5	2.8
78	1.0	1.2	1.4	1.7	2.0	2.4	2.8	3.1
80	1.1	1.3	1.5	1.8	2.2	2.6	3.1	3.5
82	1.2	1.4	1.7	2.0	2.5	2.9	3.4	3.9
84	1.3	1.5	1.8	2.2	2.7	3.2	3.7	4.3
86	1.4	1.7	2.0	2.4	2.9	3.4	4.0	4.6
88	1.6	1.8	2.1	2.6	3.1	3.7	4.2	4.9
90	1.7	2.0	2.3	2.7	3.3	3.9	4.5	5.2
92	1.8	2.1	2.4	2.9	3.5	4.2	4.8	5.6
94	1.9	2.2	2.6	3.1	3.8	4.4	5.1	5.9
96	2.0	2.3	2.7	3.3	4.0	4.6	5.4	6.3
98	2.1	2.4	2.9	3.4	4.2	4.9	5.7	6.6
100	2.2	2.6	3.0	3.6	4.4	5.1	6.0	6.9
102	2.3	2.7	3.2	3.8	4.6	5.4	6.3	7.2
104	2.4	2.9	3.3	4.0	4.8	5.7	6.6	7.5
106	2.5	3.0	3.5	4.2	5.0	5.9	6.9	7.9
108	2.7	3.1	3.6	4.3	5.2	6.2	7.2	8.2
110	2.8	3.2	3.7	4.4	5.4	6.4	7.5	8.5
112	2.9	3.3	3.9	4.6	5.6	6.7	7.7	8.8
114	3.0	3.4	4.0	4.7	5.8	6.9	7.9	9.1
116	3.1	3.6	4.1	4.9	6.0	7.1	8.2	9.4
118	3.2	3.7	4.3	5.1	6.2	7.3	8.5	9.8
120	3.3	3.8	4.4	5.3	6.4	7.5	8.8	10.1

(This table is calculated from the same data as Table II, Circular No. 57, Bureau of Standards.)

SPECIFIC GRAVITY—TEMPERATURE CORRECTIONS

TEMPERATURE CORRECTIONS TO READINGS OF SPECIFIC GRAVITY HYDROMETERS IN AMERICAN PETROLEUM OILS AT VARIOUS TEMPERATURES

(Standard at 60°/60° F.)

Observed temperature ° F.	Observed specific gravity						
	0.650	0.700	0.750	0.800	0.850	0.900	0.950
	Subtract from observed specific gravity						
30	0.016	0.015	0.014	0.012	0.011	0.011	0.011
32	.015	.014	.013	.012	.011	.010	.010
34	.014	.013	.012	.011	.010	.010	.010
36	.013	.012	.011	.010	.009	.009	.009
38	.012	.011	.010	.009	.008	.008	.008
40	.0105	.0095	.0090	.0080	.0075	.0070	.0070
42	.0095	.0085	.0080	.0070	.0065	.0065	.0065
44	.0085	.0075	.0070	.0065	.0060	.0060	.0055
46	.0075	.0065	.0060	.0055	.0050	.0050	.0050
48	.0065	.0060	.0055	.0050	.0045	.0045	.0040
50	.0050	.0050	.0045	.0040	.0035	.0035	.0035
52	.0040	.0040	.0035	.0030	.0030	.0030	.0030
54	.0030	.0030	.0025	.0025	.0020	.0020	.0020
56	.0020	.0020	.0020	.0015	.0015	.0015	.0015
58	.0010	.0010	.0010	.0005	.0005	.0005	.0005
	Add to observed specific gravity						
60	.0000	.0000	.0000	.0000	.0000	.0000	.0000
62	.0010	.0010	.0010	.0005	.0005	.0005	
64	.0020	.0020	.0015	.0015	.0015	.0015	
66	.0030	.0030	.0025	.0025	.0020	.0020	
68	.0040	.0040	.0035	.0030	.0030	.0030	
70	.0050	.0050	.0045	.0040	.0040	.0035	
72	.0060	.0055	.0050	.0045	.0045	.0040	
74	.0070	.0065	.0060	.0055	.0050	.0050	
76	.0080	.0075	.0070	.0065	.0060	.0055	
78	.0090	.0085	.0080	.0070	.0065	.0065	
80	.010	.009	.008	.008	.007	.007	
82	.011	.010	.009	.008	.008	.007	
84	.012	.011	.010	.009	.009	.008	
86	.013	.012	.011	.010	.009	.009	
88	.014	.013	.012	.011	.010	.010	
90	.015	.014	.013	.012	.011	.010	
92	.016	.015	.013	.012	.011	.011	
94	.017	.016	.014	.013	.012	.012	
96	.018	.016	.015	.014	.013	.013	
98	.019	.017	.016	.015	.014	.013	
100	.020	.018	.017	.015	.014	.014	
102	.021	.019	.018	.016	.015	.015	
104	.022	.020	.018	.017	.016	.015	
106	.023	.021	.019	.017	.016	.016	
108	.024	.022	.020	.018	.017	.017	
110	.025	.023	.021	.019	.018	.017	
112	.026	.024	.022	.020	.019	.018	
114	.027	.025	.022	.020	.019	.019	
116	.028	.026	.023	.021	.020	.019	
118	.029	.026	.024	.022	.021	.020	
120	.030	.027	.025	.023	.022	.021	

(This table is calculated from the same data as Table I, Circular No. 57, Bureau of Standards.)

FLASH- AND FIRE-POINTS

The "Flash-point" of an oil is that temperature to which the oil must be heated, at a specified rate, so that enough vapor is freed from its surface to flash or momentarily ignite when a small flame is applied to it.

The "Fire Test" of an oil is that temperature to which the oil must be heated, at a specified rate, so that it takes fire and burns continuously when a small flame is applied to its surface.

* **METHODS OF TESTING.**—The tests for flash- and fire-points of lubricating and industrial oils are usually conducted in an open cup tester, such as shown in Fig. 7, Sec. 6.

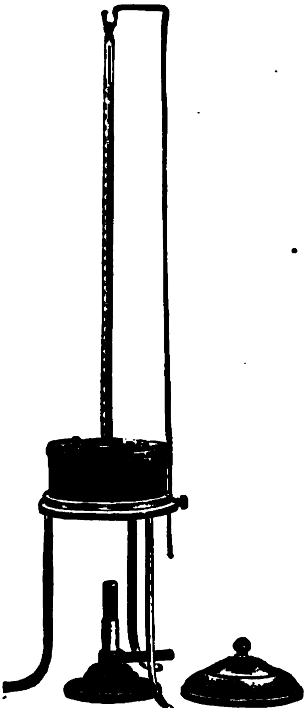


FIG. 7. SEC. 6.—Cleveland open cup flash and fire tester.

† This instrument consists merely of a solid brass cup, about 2 1/2 inches in diameter and about 1 1/8 inches deep. A thermometer is suspended in the centre of the dish so that its bulb is about 1/4 inch below the oil surface. About 3/4 inch of the oil to be tested is poured into the cup and heat is applied slowly, so that the temperature of the oil increases at the rate of 10° Fahr. per minute. A small flame from a taper or gas tube is passed across the surface of the oil when the thermometer indicates 275° Fahr. for engine oils and 425° Fahr. for cylinder oils. The test flame is then applied for every 5° Fahr. rise in temperature, until the vapor momentarily ignites or flashes, which is indicated by a faint puff of blue flame. The temperature is then noted and is the *flashing-point*. The temperature is then increased slowly until the test flame ignites the surface of the oil and causes it to continue to burn. The temperature of the oil is noted and is called *the fire-point*.

Usually the fire-point is about 45° to 75° Fahr. higher than the flash-point for engine oils. The difference is greater for high-test cylinder oils, ranging as high as 85° or 90° Fahr.

Another method of obtaining the flash- and fire-points is the "closed-cup" method. This test, as the name indicates, is carried on in a closed compartment, heated in the usual manner. The results differ by 15° or 20° lower than the tests obtained by the open-cup method.

NOTE. See Technical Paper No. 49 of the U. S. Bureau of Mines for further information on flash and fire testing.

If the oil tested contains moisture, it will froth at 212° Fahr.

When testing illuminating oils, the cup is filled in the same manner

* See index for test method of Committee on Standardization of Petroleum Specifications.

† Different cup for illuminating oils, etc.

as above described, but the heating is done at only 2° Fahr. per minute. Care must be taken when applying the flame not to allow it to touch the surface.

DIFFERENCES BETWEEN OPEN AND CLOSED CUP TESTERS.—The vapors evolved from mineral oils in the open tester escape more easily and less regularly through drafts of air than is the case with the closed cup tester, which is only open for a short time. For this reason the flash-point in the open vessel will always be higher than will be obtained from the closed vessel (Pensky-Marten). See Fig. 8, Sec. 6. The differences usually range from 5° to 40° Fahr. The Abel-Pensky tester is shown in Fig. 9, Sec. 6.

FIG. 8. SEC. 6.—Pensky-Martin flash tester.

FIG. 9. SEC. 6.—Abel-Pensky's U. S. Bureau of Mines model flash and fire tester.

EFFECT ON FLASH-POINT OF CYLINDER OILS BY NAPHTHA.—F. Schwartz found that the addition of 1/10 per cent. of naphtha to a fat-free cylinder oil reduced the Pensky flash-point 100° Fahr., and the addition of 1/30 per cent. caused a drop of 70°, while the addition of 1/60 per cent. caused it to drop 20°.

According to Holde and Muller, the addition of 0.5 per cent. of naphtha to an oil which originally flashed at 180° Fahr. in the Pensky apparatus and at 200° Fahr. in the open tester lowered the flash-point in

the Pensky apparatus to below 80° Fahr., while in the open vessel it remained the same. At the same time the viscosity of the oil decreased 8 per cent.

THE TAG CLOSED FLASH TESTER FOR INFLAMMABLE LIQUIDS.—The form of this instrument is shown in Fig. 10, Sec. 6. The parts of the instrument are keyed and are named as follows:

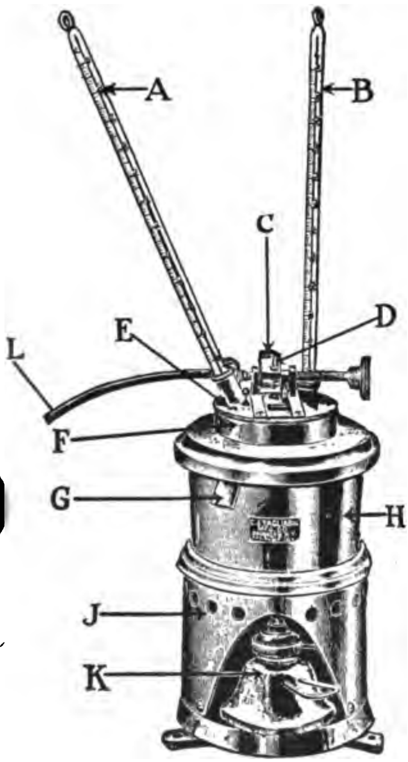


FIG. 10, SEC. 6.—Tag tester, made by C. J. Tagliabue Mfg. Co.

The tester consists essentially of the following parts, as indicated by letters on the illustration:

A Thermometer, indicating the temperature of the oil.

B Thermometer, indicating the temperature of the water bath.

C A miniature oil well to supply the test flame when gas is not available, mounted on the axis about which the test flame burner is rotated, which axis is hollow and provided with connection on one end for gas hose, and provided also with needle valve for controlling gas supply when gas is available, the gas passing through the empty oil well.

D Gas or oil tip for test flame.

E Cover for oil cup, provided with three openings, which are in turn covered by a movable slide operated by a knurled hand knob, which also operates the test-flame burner in unison with the movable slide, so that by turning this knob, the test flame is lowered into the middle opening in the cover, at the same time that this opening is uncovered by the movement of the slide.

F Oil cup (which cannot be seen in the illustration), of standardized size, weight and shape, fitting into the top of the water bath.

G Overflow spout.

H Water bath, of copper, fitting into the top of the body, and provided with an overflow spout and openings in its top, to receive the oil cup and water bath thermometer.

J Body, of metal, attached to substantial cast metal base, provided with three feet.

K Alcohol lamp for heating the water bath.

L Gas hose.

The method of operation of the Tag Tester is as follows:

If gas is available, connect a 1/8-inch rubber tube to the corrugated gas connection on the oil cup cover. If no gas is available, unscrew the test flame burner-tip from the oil chamber on the cover, and insert a wick of cotton cord in the burner-tip and replace it. Put a small quantity of

cotton waste in the oil chamber, and insert a small quantity of signal, sperm or lard oil in the chamber, light the wick and adjust the flame, so that it is exactly the size of the small white bead mounted on top of the tester.

GENERAL

1. The test must be performed in a dim light so as to see the flash plainly.

2. Surround the tester on three sides with an enclosure to keep away draughts.

A shield about eighteen inches square and 2 feet high, open in front, is satisfactory. But any safe precaution against all possible room draughts is acceptable. Tests made in a laboratory hood or near ventilators will give unreliable results..

3. See that tester sets firm and level.

4. For accuracy, the flash-point thermometers, which are especially designed for the instrument, should be used, as the position of the bulb of the thermometer in the oil cup is essential.

WATER BATH

5. Put the water-bath thermometer in place.

6. Place a receptacle under the overflow spout to catch the overflow.

7. Fill the water bath with water at such a temperature that, when testing is started, the temperature of the water bath will be at least 10° C. below the probable flash-point of the oil to be tested.

OIL CUP

8. Put the oil cup in place in the water bath.

9. Measure 50 c.c. of the oil to be tested in a pipette or a graduate, and place in oil cup. The temperature of the oil must be at least 10° C. below its probable flash-point when testing is started.

10. Destroy any bubbles on the surface of the oil.

11. Put on cover, with flash-point thermometer in place and gas tube attached.

12. Light pilot light on cover and adjust flame to the size of the small white bead on cover.

HEATING

13. Light and place the heating lamp, filled with alcohol, in base of tester and see that it is centrally located. Adjust flame of alcohol lamp so that temperature of oil in cup rises at the rate of about 1° C. per minute, or not faster than 1.1°, or slower than .9° per minute.

TESTING

14. Record the barometer pressure which, in the absence of a laboratory instrument, may be obtained from the nearest Weather Bureau Station.

15. Record the "temperature of the water bath at start."

16. Record the "temperature of the oil sample at start."

17. When the temperature of the oil reaches about 5° C. below the probable flash-point of the oil, turn the knob on the cover so as to introduce the test flame into the cup, and turn it *promptly* back again. Do not let

it snap back. *The time consumed in turning the knob down and back should be about one full second,* or the time required to pronounce distinctly the words "one thousand and one."

18. Record the "time of making the first introduction of the test flame."

19. Record the "temperature of the oil sample at time of first test."

20. Repeat the application of the test flame at every 1/2° C. rise in temperature of the oil until there is a flash of the oil within the cup. Do not be misled by an enlargement of the test flame or halo around it when entered into the cup, or by slight flickering of the flame; the true flash consumes the gas in the top of the cup and causes a very slight explosion.

21. Record the "time at which the flash-point is reached."

22. Record the "flash-point."

23. If the rise in temperature of the oil, from the "time of making the first introduction of the test flame" to the "time at which the flash-point is reached," was faster than 1.1° or slower than .9° per minute, the test should be questioned, and the alcohol heating lamp adjusted so as to correct the rate of heating. It will be found that the wick of this lamp can be so accurately adjusted as to give a uniform rate of rise in temperature of 1° per minute and remain so.

REPEAT TESTS

24. It is not necessary to turn off the test flame with the small regulating valve on the cover; leave it adjusted to give the proper size of flame.

25. Having completed the preliminary test, remove the heating lamp, lift up the oil-cup cover, and wipe off the thermometer bulb. Lift out the oil cup and empty and carefully wipe it. Throw away all oil samples after once using in making test.

26. Pour cold water into the water bath, allowing it to overflow into a receptacle, until the temperature of the water in the bath is lowered to 8° C. below the flash-point of the oil, as shown by the previous test. With cold water of nearly constant temperature, it will be found that a uniform amount will be required to reduce the temperature of the water bath to the required point.

27. Place the oil cup back in the bath and measure into it a 50 c.c. charge of fresh oil. Destroy any bubbles on the surface of the oil, put on the cover with its thermometer, put in the heating lamp, record temperature of oil and water, and proceed to repeat test as described above, in Sections 8 to 22 inclusive. Introduce test flame for first time at a temperature of 5° C. below the flash-point obtained on the previous test.

GENERAL

If two or more determinations agree with 1/2° C., then the average of these results, corrected for barometric pressure, shall be considered the flash-point. If two determinations do not check within 1/2° C., a third determination shall be made, and, if the maximum variation of the three tests is not greater than 1° C., then their average, after correcting for barometric pressure, shall be considered the flash-point.

CORRECTION FOR BAROMETRIC PRESSURE

A correction table is furnished with each instrument for converting the results of tests made at varying barometric pressures to equivalent temperatures, at the standard barometric pressure of 760 mm.

* **FIRE TEST.**—(Test method used U. S. Div. Military Aeronautics, acknowledgments A. S. T. M.). The fire test of an oil is the temperature at which the vapors are given off in sufficient quantities to continue burning. The test is made by continuing the same operation as in taking the flash test, except in the application of the test flame. The flame in the fire test is quickly brought to 1/16 inch above the surface of the oil near the centre of the cup and as quickly removed. The Fire Test is from 40° to 80° higher than the flash, and after the latter test has been obtained, the application of the testing flame may safely be discontinued in the case of the engine oils for 30°, and in the case of cylinder oils 50°, before they are again applied to obtain the fire test.

PRECAUTIONS.—Care should be exercised that oils are free from water before starting the flash test, and that under no circumstances should oil above 212° be brought in contact with water. Hot oil should never be poured into receptacles containing inflammable liquids or gases.

FLASH TEST.—(Test methods, U. S. Div. Military Aeronautics, acknowledgment A. S. T. M.). The flash-point of an oil is the lowest temperature at which the vapors on its surface will ignite and burn momentarily on application of flame or spark. The apparatus in common use is the Cleveland Open Cup, which consists of two parts; one the oil-holder, the other the bath for containing the oil or sand for modifying the source of heat. The bath can be dispensed with by using instead a brass or other metal plate 5 inches in diameter by 1/4 inch thick, and slightly recessed on its upper face to receive the base of the oil-holder. The metal plate or bath is usually mounted on a tripod to which a wire is attached for supporting a thermometer. The latter may be supported by a clamp on a ring stand or by a chain. The thermometer used should be of the engraved chemical stem pipe, corrected for 1 inch immersion, graduated in double degrees and reading to approximately 700° F. The bulb should be about 3/8 inch long, not exceeding 1/2 inch. The thermometer should be suspended in the exact centre of the cup and free from the bottom at least 1/8 inch. Pour carefully into the holder enough oil to compensate for the expansion due to heating. Cylinder oils, because flashing higher than engine oils, show greater expansion at their flash-points and require an outage, cold, of about 3/8 inch.

Avoid overheating locally by wiping the flange free of oil and not allowing oil to be spattered up the sides of the cup.

The oil should be heated at a uniform rate of 10° per minute and at approximately 25° below the expected flash the test flame should be applied by resting the gas tube on the edge of the cup and searching for the flash in a semi-circle around the thermometer, midway between it and the inside edge of cup, carrying the flame level with the top of the cup. This should be repeated at every rise of 5° in temperature until a flame appears at several points or covers at least one-half of the cup and immediately goes out.

The testing flame is provided by using a slender tube tapered at the end to an opening of approximately 1/16 inch in diameter. The flame should be in the form of a bead and not more than 1/8 inch in diameter.

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* See index for Committee on Standardization of Petroleum Specifications Method.

COLD TEST

There are two definitions of Cold Test; *i. e.,* Cloud Test and Pour Test, and any reference to cold test should always include the statement of the method used to obtain it.

* **CLOUD TEST.**—When paraffin-base oils are cooled to a low enough temperature, they become cloudy, due to the separation of the finely divided particles of paraffin in the oil. The temperature at which this separation can first be seen is called the Cloud Test of that oil.

When obtaining the Cloud Test, the rate of cooling the oil must be uniform. The oil is usually cooled in a four-ounce sample bottle, having its top broken off. The bottle is placed in a tin holder, with blotting-paper around it to prevent too rapid cooling of the oil. The tin holder is put into a cold brine solution, and by means of special cold-test thermometer the temperature is noted at the first clouding of the oil.

(Test methods, Div. Military Aeronautics, U. S., acknowledgment to A. S. T. M.) The cloud test indicates the point at which paraffin wax or other solid substances crystallize out or separate from solution in the oil.

Put the oil to be tested in a glass jar or bottle of approximately 1 1/4 inches inside diameter and 4 to 5 inches high, to a height of about 1 1/4 inches, or sufficient to reach 1/4 inch above the mercury bulb of the thermometer. The thermometer used is the so-called cold-test thermometer, which is specially made for this purpose and has a bulb 1/4 to 3/8 inch long. Insert the thermometer through a tight-fitting cork, so that it is centrally held in the jar, with the lower end of the bulb 1/2 inch from the bottom of the jar. Then place the cold-test jar in a metal or glass jacket 4 to 5 inches high, having inside diameter 1/2 inch larger than the outside diameter of the test jar. A disk of felt, cork or wax 1/4 inch in thickness is placed in the bottom of the jacket so that it does not touch the sides at any point. Then put the whole apparatus into the refrigerating mixture, and at every drop in temperature of 2° F., when near the expected cloud test, remove the jar from the jacket and inspect, being careful not to disturb the oil by moving the thermometer or otherwise. When the lower half of the sample becomes opaque through chilling, read the thermometer. This reading shall be taken as the cloud test of the oil.

† **A TYPICAL TEST METHOD FOR CLOUD TEST.**—As an indication of a systematic method of obtaining the Cloud Test of an oil, the following outline of the method used by the laboratory of a large oil refining company is given:

The oil is placed in a cold-test tube having the following dimensions: 35 mm. diameter, 130 mm. long to the depth of 20 mm. 3/4 inch. The thermometer is placed in the tube resting on the bottom. The tube is placed in a bath of cold water, oil or freezing mixture of low enough temperature to cause separation of paraffin from the oil; that is, 10–15° Fahr. below the expected cloud. The oil is stirred gently. The temperature at which cloudiness appears at the lower edge of the oil is noted. The temperature of the bath will usually be 5/8° Fahr. lower than that of the oil when cloud appears.

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* This, of course, refers to light oils, lubricating oils, etc., fractions, which are clear enough to indicate when cloud appears.

† See index for Committee on Standardization of Petroleum Specifications Method of Test.

* **POUR TEST.**—The Pour Test of an oil is the lowest temperature at which the oil will "run." The Pour Test must be very carefully made to obtain any degree of accuracy.

To a tube about 1 1/2 inches in diameter and 5 inches long is fitted a cork with a thermometer pushed through it so that the bulb is held firmly about an inch from the bottom of the tube. About 2 1/2 inches of oil is poured into the tube and slowly cooled. Every five degrees the tube is tilted, to show whether the oil will run. When it becomes so stiff that no movement can be noted for ten seconds, the Pour Test is taken at 5° Fahr. above the temperature of the solid oil.

The following outline of a method for making a Pour Test of an oil is given in the following abstract from Proceedings of the American Society for Testing Materials, Volume 17, 1917: The Pour Test is an indication of the temperature at which a sample of oil will begin to flow in a cylindrical container of specified diameter and length and under specified conditions. The apparatus for making the test is as follows:

1. A glass jar, approximately 1 1/4 inches inside diameter and 4 to 5 inches in height, provided with a tightly fitting cork.

2. Mercury thermometer, fitted securely in the cork so that the stem will be held centrally in the jar with the tip of the bulb 1/2 inch from the bottom. The thermometer, which is specially designed for this purpose, has a bulb 1/4 to 3/8 inch in length.

3. A metal jacket, fitted closely around the jar and provided at the bottom with a disk of cork or felt of about 1/4 inch in thickness. The method of testing is as follows:

The oil is placed in the jar to a depth of about 1 1/4 inches, or to a sufficient depth to reach (1/4 inch) above the bulb of the thermometer; the cork is fitted tightly into the jar and the jar is placed into the metal jacket; then the metal jacket is placed into the freezing mixture. As the temperature drops 5° Fahr. the jar is removed each time and tilted just enough to make the oil flow. The pour test is taken as 5° Fahr. above the temperature reading, obtained when the oil has been cooled to the point that it will not flow when the jar is tilted in a horizontal position. The rate of cooling is such that the pour test will be completed in about one-half hour. The following materials are used for obtaining different freezing mixtures, the choice depending upon the temperature required to cause the oil to solidify:

For temperatures above +35° Fahr. use: Cracked ice.

For temperatures between +15 and +35° Fahr. use: One volume of salt † and 20 volumes of ice.

For temperatures between —5° Fahr. and 15° Fahr. use: Ice and salt in proportions of one to two.

For temperatures 0° to minus 25° Fahr. use: Mixture of ice and calcium chloride.

For temperatures lower than —5° Fahr., a mixture of solid carbon dioxide and acetone is more convenient and will give temperatures of —70° Fahr. or less.

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* See index for Committee on Standardization of Petroleum Specifications Method.

† Note. The salt for this purpose should be dry and fine enough to pass through a 20-mesh screen.

The method of making the carbon dioxide-acetone mixture is as follows: A sufficient quantity of dry acetone is placed in a covered copper or nickel beaker. The beaker is placed in an ice-salt mixture, and when the acetone reaches 10° Fahr. or less, the solid carbon dioxide is added until the desired temperature is reached. To obtain the solid carbon dioxide, an ordinary carbon dioxide cylinder is inverted and the valve carefully opened. The escaping gas is then caused to flow into a chamois-skin bag. The rapid evaporation will cause the carbon dioxide to solidify.

A TYPICAL METHOD FOR POUR TEST.—The following method is in use by the laboratory of a large oil company and is given as an example of testing method: Sixty mm. (2 1/2 inches) of oil are placed in a cold-test tube. A cork is put in top, through which a thermometer is stuck, which dips into the oils 5/8 inch. The temperature of the oil when poured into the tube should be at least 30° Fahr. above the estimated pour point of the oil. The tube is cooled in a cooling bath, and while cool is removed quickly. When the oil starts to congeal, the tube is taken from the bath and inclined for not longer than 10 seconds. The cooling is continued until the tube can be inverted to 135° for 10 seconds without the oil flowing. Five degrees Fahr. are added to the temperature as noted at this point and the result is taken as the "pour point" of the oil.

POUR TEST.*—The pour test indicates the temperature at which a sample of oil in cylindrical form of specified diameter and length will just flow under specified conditions. In making this test the same bottle and quantity of oil are used as for the cloud test, and the pour test may, if desired, be taken after the cloud test has been determined, in the great majority of cases, the cloud test being the higher. In making the pour test place the jar containing the oil in a close-fitting metal jacket, provided at the bottom with a disk of felt or cork 1/4 inch thick. Place this in the freezing mixture. At each drop in temperature of 5° F. remove the bottle from the jacket and tilt it until the oil begins to flow; just sufficiently tilted, but no more. In the extreme case, the bottle should be tilted to the horizontal. When the oil has become solid around the thermometer and will not flow, the previous 5° point shall be taken as the "pour test" of the oil. Preferably the cold should be applied so that the pour test will be completed in approximately one-half hour. The materials used in the freezing mixture may be ice, calcium chloride or sodium chloride, or solid carbon dioxide with acetone, depending upon the temperature desired in making the tests. For oils congealing or solidifying above +35° F. pounded ice is used. From +35 to +15° F., a mixture of pounded ice and a small addition of salt, one to twenty by volume, may be taken. From temperatures from +15 to —5° F. also use an ice-and-salt mixture, adding about one-third salt. The salt should be very dry and granulated fine enough to pass through a 20-mesh sieve. From zero to —25° F. a mixture of ice and calcium chloride is used. For temperatures lower than —5° F., however, it will be found very convenient to use solid carbon dioxide and acetone, by which any desired temperature down to —70° F. can be obtained, or even lower. This freezing mixture is made as follows: Take a sufficient amount of dry acetone and

* From test methods, Div. Military Aeronautics, U. S. A.

put into a covered metal beaker, copper or nickel; put the beaker into an ice-salt mixture, and when the temperature of the acetone reaches +10° F. or below, add by degrees solid carbon dioxide until the desired temperature is reached. To get the solid carbon dioxide, take an ordinary liquefied carbon dioxide cylinder and invert it, open the valve carefully and let the gas run out into a chamois-skin bag. By the rapid evaporation the dioxide becomes solid.

* **COLD TEST FOR STEAM CYLINDER AND BLACK OILS.**—The object of this test is to determine the lowest temperature at which an oil will flow from one end of a container to the other, in case it should become frozen and the resulting solid oil stirred till it has assumed a sufficiently pasty consistency to flow. The test is conducted by freezing an ounce of the oil solid in an ordinary four-ounce oil sample bottle using a freezing mixture if necessary. A thermometer should then be introduced into the frozen mass. After it has become cold the bottle containing the congealed oil is removed from the cooling medium. The frozen oil is thoroughly stirred with the thermometer until the mass will run from one end of the bottle to the other and at this moment the temperature as indicated is recorded. The reading is the cold test of the oil. If the figures † indicating the cold test are inside the bottle and covered by the softened oil, the reading can be obtained by grasping the bottle by the neck with one hand, having in the same hand a piece of waste, which encloses the thermometer. The thermometer is then withdrawn through the waste with the other hand for a sufficient distance to enable the operator to see the end of the mercury column and read the temperature.

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* See index for Committee on Standardization of Petroleum Specifications Method of Test.

† On the thermometer scale.

VISCOSITY AND ITS MEASUREMENT

VISCOSITY.—Viscosity is a measure of fluidity or rate of flow of an oil. Its value depends upon the internal friction between the particles composing the oil and their resistance to separation. It is closely related to the internal properties of cohesion and adhesion.

* **MEASUREMENT.**—Viscosity is measured by means of a viscosimeter. There are various types of viscosimeters on the market. Some depend upon the time required for a given quantity of the oil to flow through an orifice in the bottom of a container. Others are based upon the resistance to motion offered a disk, rotating, immersed in the oil. The rate of flow viscosimeter is the type in most general use.

VISCOSITY.—(Test methods U. S. Div. Military Aeronautics, acknowledgment A. S. T. M.). The viscosity tests are obtained by the Saybolt Universal Viscosimeter, the temperature of the oil being 100°, 130° and 212° F. The bath of these temperatures should be held at, respectively, 100.5°, 131° and 214° F. Heat the bath to the required temperature, swab the oil tube with the plunger accompanying the instrument, using the oil to be tested making sure that the outflow tube is not obstructed. Place the cork in position in the outlet, strain the oil into the oil tube at a temperature not above that of the bath, stir the oil until it is shown to be throughout of the exact temperature of the test; remove the thermometer, suck out the excess oil from the overflow chamber with a pipette; place the flask directly below the cork, and, with stop-watch in one hand, pull the cork with the other, starting the watch at the same instant. The elapsed time in seconds required for the oil to fill the flask to the 60 c.c. mark on the neck is given as the viscosity of the oil. (It will be necessary to use a bath of light lubricating oil in order to maintain it at 214° when taking the viscosity of the oil at 212° F.)

SAYBOLT VISCOSIMETER.—The most widely used instrument in the United States for measuring viscosity is the Saybolt viscosimeter. The instrument is essentially composed of a covered oil receptacle of a carefully determined shape and size, provided at the bottom with a standard orifice and a valve, the valve being constructed to quickly open or shut the orifice as desired. The cup is supported in an outer cup, which is filled with a pale engine oil of about 375° Fahr. flash-point, or, for some cases, water is used as a bath in the outer cup. See Fig. 11, Sec. 6.

Briefly, the measurement of viscosity with the Saybolt instrument may be described as follows: The oil cup is filled with a standard quantity of the oil to be tested, and after it has been heated to the desired temperature and kept constant for two or three minutes the bottom orifice is opened. The oil is then run into a 60 c.c. flask and the number of seconds, as noted by means of a stop-watch, that are required for the flow of the oil through the orifice into the flask to fill it to the 60 c.c. mark is reported as the viscosity of the oil.

The Saybolt Universal viscosimeter has always been at a disadvantage, as compared with the Engler instrument, generally used in Germany, because it had never been standardized with respect to its principal dimensions. To overcome this difficulty the Bureau of Standards entered

* See index for Committee on Standardization of Petroleum Specifications Test Method.

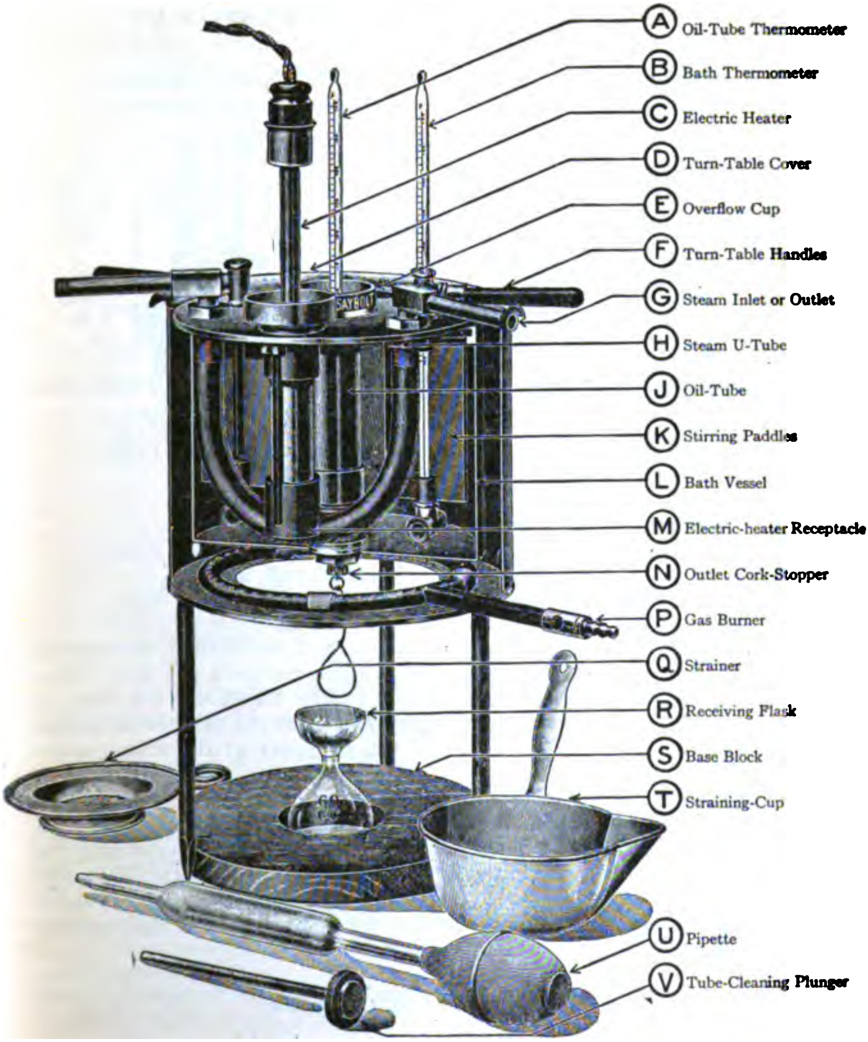

FIG. 11. SEC. 6.—Saybolt standard universal viscosimeter. (View shows one-half of stand jacket and bath vessel, cut away to show inside parts.

into negotiations with Mr. George M. Saybolt, and he agreed to accept certain instruments as standard.

It has long been realized that the Saybolt instrument would remain at a great disadvantage in competition with the Engler, until it was standardized by the adoption of normal dimensions and suitable tolerances.

Table 1 gives the normal dimensions and allowable variations proposed by the Bureau of Standards.

Table 1.—Dimensions of the Standard Saybolt Universal Viscosimeter

Dimension	Minimum	Normal	Maximum
	cm.	*cm.*	*cm.*
Diameter of outlet tube, d	0.1750	0.1765	0.1780
Length of outlet tube, l	1.215	1.225	1.235
Outer diameter of outlet tube, at lower end, d_3	.28	.30	.32
Height of overflow rim above bottom of outlet tube, h_1	12.40	12.50	12.60
Diameter of container, D	2.955	2.975	2.995
Average head, h (calculated)	7.16	7.36	7.56

The standard testing temperatures with the Saybolt viscosimeter for various oils are as follows:

(*a*) For testing cylinder, valve, and similar oils ...212° Fahr.
NOTE. This temperature is generally referred to as 212° Fahr. for the temperature of the bath and 210° for the oil.

(*b*) For testing reduced black oils, bath oil, at .... 130° Fahr.

* (*c*) For testing neutral, spindle, paraffin, red, and other distilled oils, bath and oil, at ....100° Fahr.

ENGLER VISCOSIMETER.—In the use of the Engler instrument for determining viscosity, the so-called Engler numbers are very often used instead of the time in seconds. The Engler number is the time of outflow of 200 c.c. of the oil under investigation at the test temperature, divided by the time of outflow of 200 c.c. of water at the temperature of 20° C.

As a matter of interest, with the Engler instruments, having the standard dimensions specified for them, the time of outflow of 200 c.c. of water at 20° C. is about 50 to 52 seconds. In order to demonstrate the method of determining the Engler number, assume that the observed time for the outflow of 200 c.c. of tested oil was 150 seconds. Then, if the "water constant," or time of outflow for 200 c.c. of water, at a temperature of 20° C. is 51:

$$\frac{150}{51} = 2.94, \text{ is the Engler Number.}$$

Fig. 12, Sec. 6, shows the latest form of Engler's viscosimeter. The instrument consists of an oil container, which is gold-plated on the inside, with a platinum outlet. It is surrounded with a brass water bath. It is equipped with two thermometers, one reading to 150° C. and the other to 50° C. A graduated flask, tripod and ring burner complete the

* Some specifications adopt 130° Fahr. in place of 100° Fahr.

outfit. Fig. 13, Sec. 6, shows a form of Engler viscosimeter modified by Ubbelohde, with an air space in the lid and a stirring arrangement to maintain constant temperatures to increase the accuracy of the readings.

FIG. 12. SEC. 6.—Engler's viscosimeter.

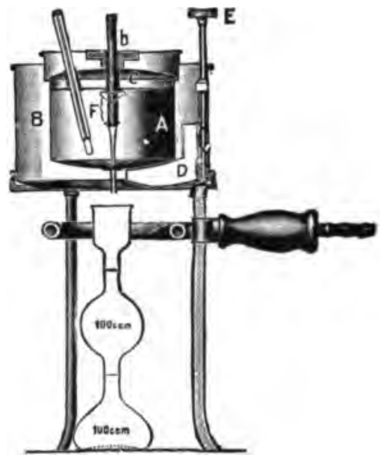

FIG. 13. SEC. 6.—Engler's viscosimeter, modified by Ubbelohde.

Standard Dimensions of Engler Viscosimeter *

Specified distances	Normal dimensions	Tolerance
	cm.	*cm.*
Length of outlet tube, l	2.0	±0.01
Inside diameter of outlet tube, at upper end, d_1	.29	± .002
Inside diameter of outlet tube, at lower end, d_2	.28	± .002
Outside diameter of outlet tube, d_3	.45	± .02
Length of outlet tube, projecting below bottom of the bath, l_1	.30	± .03
Inside diameter of container, D	10.6	± .10
Depth of cylindrical part of container below the gage points, h_3	2.5	± .10
Height of the gage points above lower end of outlet tube = initial head, h_1	5.2	± .05

UBBELOHDE'S VISCOSIMETER.—Fig. 14, Sec. 6, shows a view of this instrument. It can indicate closer differences than is possible with the Engler instrument. The cup is wider than the Engler cup and is shallower. It is provided with an overflow tube, to bring the oil to the correct height quickly, and the outlet is longer and narrower.

* From Technologic Paper, U. S. Bureau of Standards, No. 112.

LEPENAU'S VISCOSIMETER.—This instrument is not in general use in America. It is designed for the direct comparison of the viscosity of two oils under similar conditions and at the same time.

DOOLITTLE'S TORSION VISCOSIMETER.—Fig. 16, Sec. 6, shows a view of this instrument. It is not in general use in the oil trade.

REDWOOD VISCOSIMETER, ADMIRALTY TYPE.—This type of viscosimeter, shown in Fig. 15, Sec. 6, is used in England for testing fuel oil. Its purpose is the testing of fuel oil for contract purposes. It is intended for use at 32° Fahr. The vessel for oil is of the same dimensions as the original Redwood instrument, but the agate jet is longer and has a larger bore. This instrument is designed

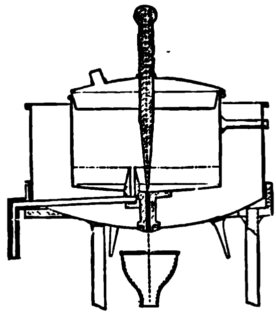

FIG. 14. SEC. 6.—Ubbelohde's viscosimeter.

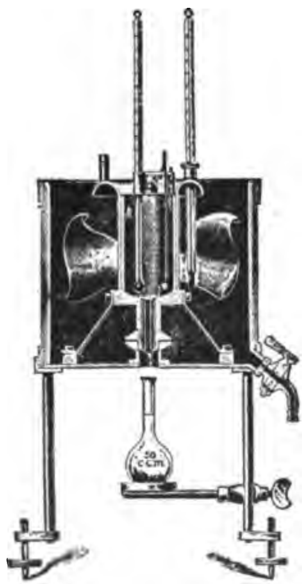

FIG. 15. SEC. 6.—Redwood's "Admiralty Type" viscosimeter, for fine oils.

FIG. 16. SEC. 6.—Doolittle's torsion viscosimeter.

to give an overflow in one-tenth the time of the original instrument for the same volume. The jet is so mounted that it can be completely surrounded with water and crushed ice, and the bath is large in size. When accurate tests are required, the oil is placed in a refrigerating chamber for at least six hours before testing, but should be thoroughly stirred before being placed in the oil chamber. The instrument itself may be placed in a refrigerating chamber and kept at 32° Fahr. if accurate results are especially desired.

Some comparative readings obtained upon the Saybolt Universal and the Redwood Admiralty type viscosimeters are as follows:

Mexican Fuels

Gravity Baumé	Viscosity Redwood Admiralty at 32° Fahr.	Saybolt at 130° Fahr.
16.5	Too viscous to flow at 32° Fahr.	1090
20.5	695	186
23.8	115	68
33.3	10	37

FIG. 17. SEC. 6.—MacMichael viscosimeter with standard and hood thrown back showing driving mechanism.

MACMICHAEL VISCOSIMETER.—This is a viscosimeter of the torsion type, having a disk suspended in a cup of the fluid to be tested. The force exerted by the rotation of the flame upon the disk is

measured. The disk is suspended by a torsion wire about 10 in. in length, which runs down through the stem of the plunger and is fastened near to the bottom. The cup is jacketed and an electric heating coil is immersed in the jacket oil.

Fig. 17, Sec. 6, and Fig. 18, Sec. 6, show two views of the viscosimeter.

The cup containing the fluid under test is rotated, and the force exerted by the rotation of the fluid on the plunger is measured.

In operating, the cup is filled to the mark on the side of the cup with the fluid to be tested. This requires about 100 c.c. The desired temperature of the oil jacket is obtained with the aid of the electric heating coil. The deflection noted on the dial is the viscosity of the fluid.

FIG. 18. SEC. 6.—MacMichael viscosimeter ready for operation.

The readings obtained are in degrees of angular deflection, 300° to the circle, designated as °M. The practical working unit is 1/1000 of the absolute unit. Water at 20° C. or 68° Fahr. has exactly 1/100 of the absolute unit of viscosity. Water at this temperature reads 10° M. Thus by shifting the decimal point, practical units, absolute units and specific viscosity may be obtained at one reading. Readings are taken directly from the dial.

The normal speed of the cup is 60 to 80 R. P. M.

Table 2, page 303, gives MacMichael-Saybolt conversion tables, as published by Eimer & Amend, New York, who sell the instrument.

CONVERSION TABLES

Table 2

MACMICHAEL-SAYBOLT VISCOSITIES

TAKEN ON LUBRICATING OILS

Temperature Degrees F.	Sample numbers					
	1	2	3	4	5	6
60°	192 366	243 419	248 517	488—MacMichael. 1016—Saybolt.		
70°	141 262	166 331	169 357	323 673	517 1084	
80°	105 191	126 238	132 259	218 467	335 706	447 1005
90°	85 144	98 177	100 190	160 323	228 484	306 658
100°	68 112	78 137	79 143	117 231	160 336	211 452
110°	58 92	66 108	66 113	94 175	124 254	156 326
120°	49 78	56 89	57 92	76 135	97 184	117 240
130°	42 67	48 75	48 77	65 109	80 142	95 183
140°	36 58	41 64	48 66	55 92	66 113	77 142
150°	32 53	36 57	37 58	47 77	57 96	66 112
160°	29 49	32 52	33 54	41 67	49 80	56 94
170°	26 46	28 48	29 49	36 59	43 69	48 80
180°	24 44	26 45	27 46	32 54	38 61	42 68
190°	22 42	24 43	24 44	29 50	34 55	37 61
200°	20 39	22 42	22 42	26 47	30 51	33 55
210°	18 38	20 39	20 40	24 44	27 47	30 50

Subject to correction upon the issuance of Standard Testing Samples by the Bureau of Standards. *Courtesy of Eimer & Amend, New York.*

COMPARATIVE VISCOSITIES

For purposes of comparison, some approximate comparative values of Redwood, Engler, Tagliabue and Saybolt viscosities are shown by the curves in Fig. 19, Sec. 6, Fig. 20, Sec. 6, and Fig. 21, Sec. 6. It must be appreciated, however, that, as the curves were obtained with oils from the Eastern and Mid-Continent crudes, the curves will not be accurate for other oils, especially at high temperatures. It is not practical to obtain

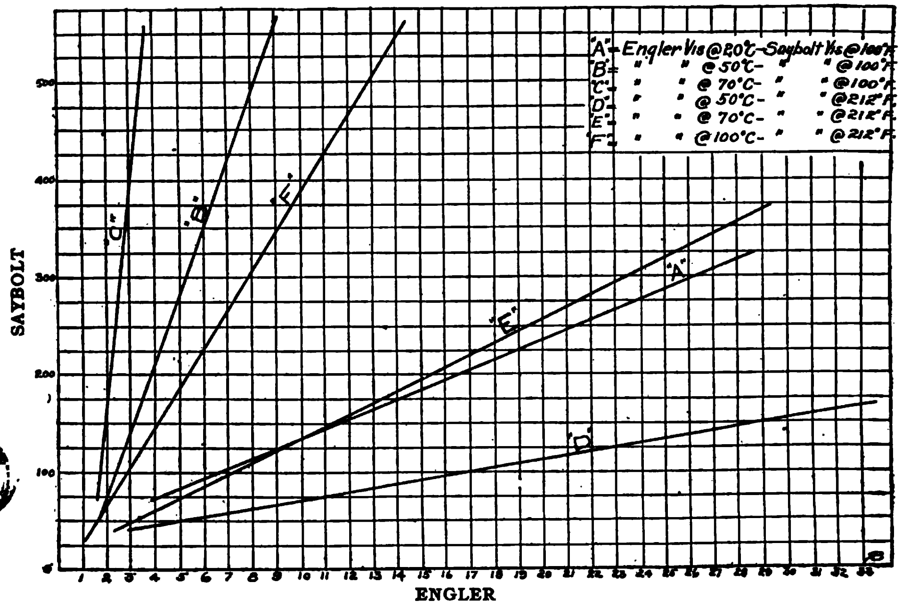

Fig. 19. Sec. 6.—Engler-Saybolt viscosities.

absolutely accurate results for comparison of the readings of the various instruments, and the trade is urged to adopt the standard Saybolt instrument, in order to standardize specifications and tests. These curves should only be used as guides, not absolute.

SAYBOLT-ENGLER VISCOSITIES.—Fig. 22, Sec. 6, shows another series of curves for comparing readings made upon the Saybolt and Engler Viscosimeters.

It should be noted that the diagram applies only to paraffin-base oils and should only be used for rough estimates. The curves were obtained by W. H. Herschel, of the Bureau of Standards.

As before stated, the rates of change as shown in the curves are for paraffin-base oils. Oils with an asphalt base may show a higher rate and compounded oils a lower rate of change.

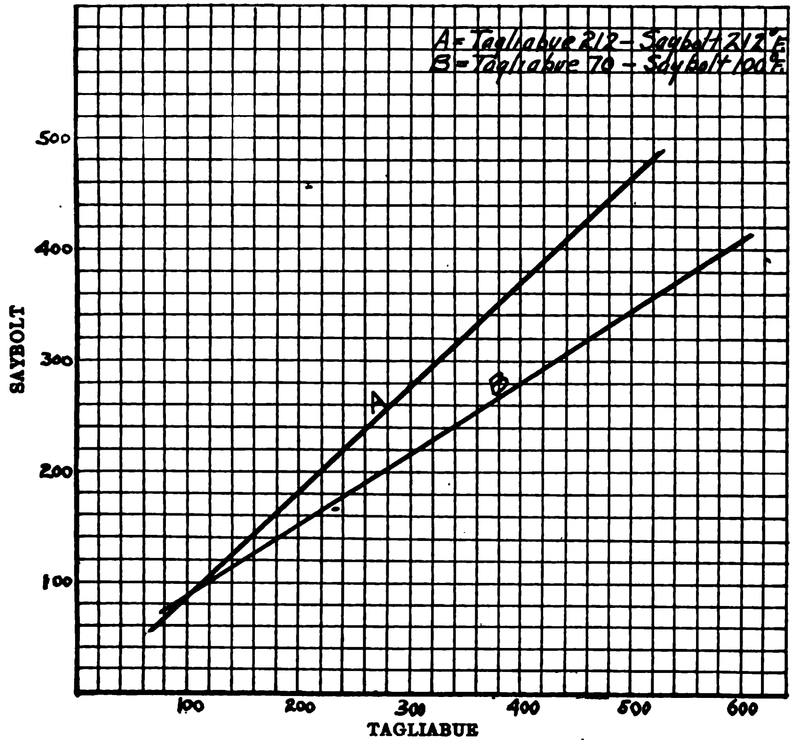

FIG. 20. SEC. 6.—Saybolt-Tagliabue curves.

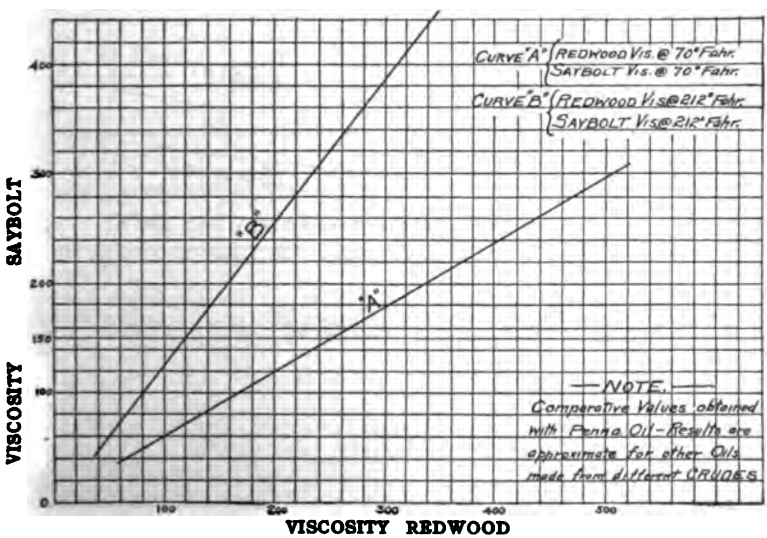

FIG. 21. SEC. 6.—Redwood-Saybolt viscosities.

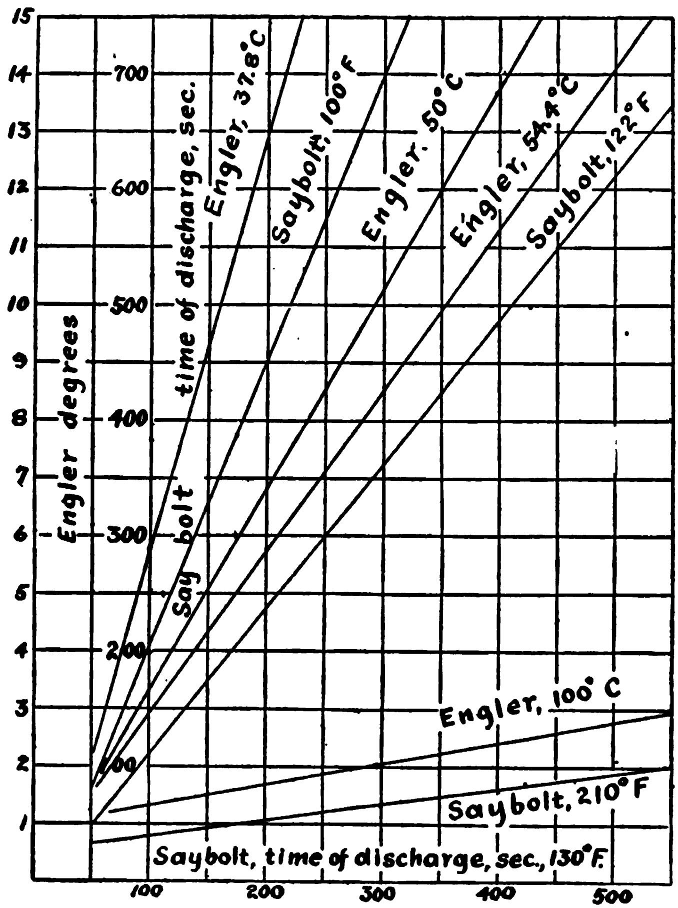

FIG. 22. SEC. 6.—Comparison of readings of the Engler and Saybolt Universal Viscosimeter at various temperatures. Note: This diagram applies only to paraffin base oils and should only be used for rough estimates. Prepared by Bureau of Standards, Winslow H. Herschel.

ABSOLUTE VISCOSITY

Mr. Winslow H. Herschel, Bureau of Standards, Washington in a technologic paper,* entitled "Determination of Absolute Viscosity by Short-Tube Viscosimeters," has prepared a highly technical and mathematical paper on this subject. It aims to formulate a method of expressing in absolute units; that is, units expressed in terms of the centimetre, the gram and the second, viscosities which have been measured in commercial viscosimeters. He defines absolute viscosity as "the force which will move a unit area of plane surface with unit speed, relative to another parallel plane surface, from which it is separated by a layer of unit thickness."

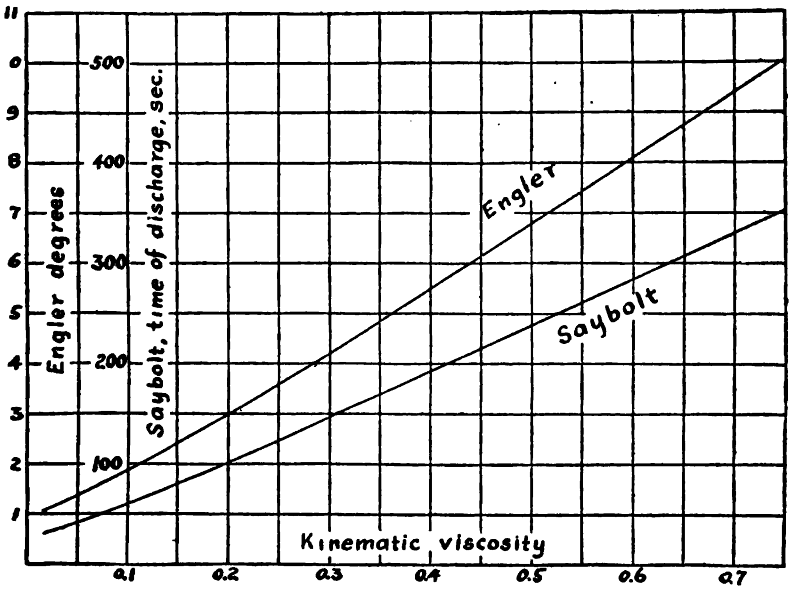

FIG. 23. SEC. 6.—Ratio of kinematic viscosity to time of discharge, as calculated by Herschel from his formulas as given, for Saybolt's Universal and Engler viscosimeters he used. U. S. Bureau of Standards, by Winslow H. Herschel.

The Engler and Saybolt Viscosimeters are discussed thoroughly by Mr. Herschel.

The following tentative equations are arrived at, by means of which kinematic viscosities can be calculated. Kinematic viscosity

† equals $V/G = 0.00213T - \frac{1.535}{T}$ for the Saybolt Universal,

* Technologic Paper No. 100, Bureau of Standards, 1917.

† Viscosimeters used: Saybolt No. 580, No. 727, No. 765; Engler No. 2204V.

* equals $V/G = 0.00147 - \frac{3.74}{T}$ for the Engler Viscosimeter,

Where V = Absolute viscosity in poises.
T = Time of flow in seconds.
G = Specific gravity of the liquid or oil.

A "poise" is a unit of the absolute system of measurements and equals one dyne per second per square centimetre. A dyne is the force, which when acting on a mass of one gram during one second, gives this mass a velocity of one centimetre per second.

Mr. Herschel gives in his report the curves shown in Fig. 23, Sec. 6, showing the ratio of kinematic viscosity to time of discharge, as calculated from the equations above for the Saybolt and Engler Universal Viscosimeters as used by him.

* In Technologic Paper No. 112, Bureau of Standards, Mr. Herschel derives formulæ for determining the absolute viscosity of the Saybolt Viscosimeter, with standardized dimensions, as described under heading, "Viscosimeters," this book. These formulæ are now being revised in accordance with final dimensions.

VISCOSITY DATA

NOTES ON VISCOSITY.—The viscosity of petroleum oils decreases as the temperature of the oil increases. The viscosities of lubricating oils made from Texas and California crudes are quite high at the standard testing temperature of 100° Fahr., as compared with the engine and machine oils made from Pennsylvania and Mid-Continent crudes.

The viscosities of lubricating oils made from asphaltic-base crudes decrease much faster as their temperatures are increased than the viscosities of lubricating oils made from paraffin-base crudes.

The effect upon the viscosities of various typical neutral oils made from northern crudes is shown in Fig. 24, Sec. 6.

A comparison of the changes in the viscosities, with increase in temperatures, of engine oils made from California, Texas, and Pennsylvania

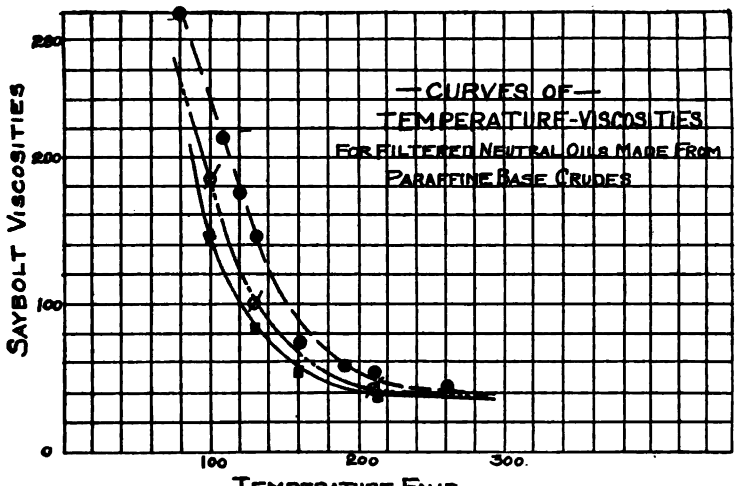

Fig. 24. Sec. 6.—Viscosity-temperature curves of filtered neutral oils (paraffin base crudes).

crudes is given by the temperatures-viscosity curves shown in the section on Petroleum.

The effect of temperature increase upon the viscosities of several cylinder oils is shown by the curves in Fig. 25, Sec. 6.

IMPORTANCE OF VISCOSITY TESTS AS A GUIDE TO LUBRICATION.—All operating engineers have had bearings of machines under their care which increased in temperature when in operation to a certain point and remained at that temperature under normal working conditions. It is not uncommon to find bearings unusually warm and yet causing no worry or anxiety to the engineer in charge, because he knows that these bearings will not heat to any higher temperatures. These conditions are not evidences of satisfactory lubrication, because excessive frictional heat in a bearing is an indication of loss of power due to an excessive frictional load; the power absorbed by friction having been transformed

into heat. The causes of the high running temperatures in the above-described bearings may be credited largely to the viscosity characteristics of the lubricating oil in use. The viscosity of the oil was too high to give satisfactory results when the bearings were developing normal running heats, and, therefore, the bearing was required to develop sufficient heat to reduce the viscosity of the oil to a working value, which allowed it to

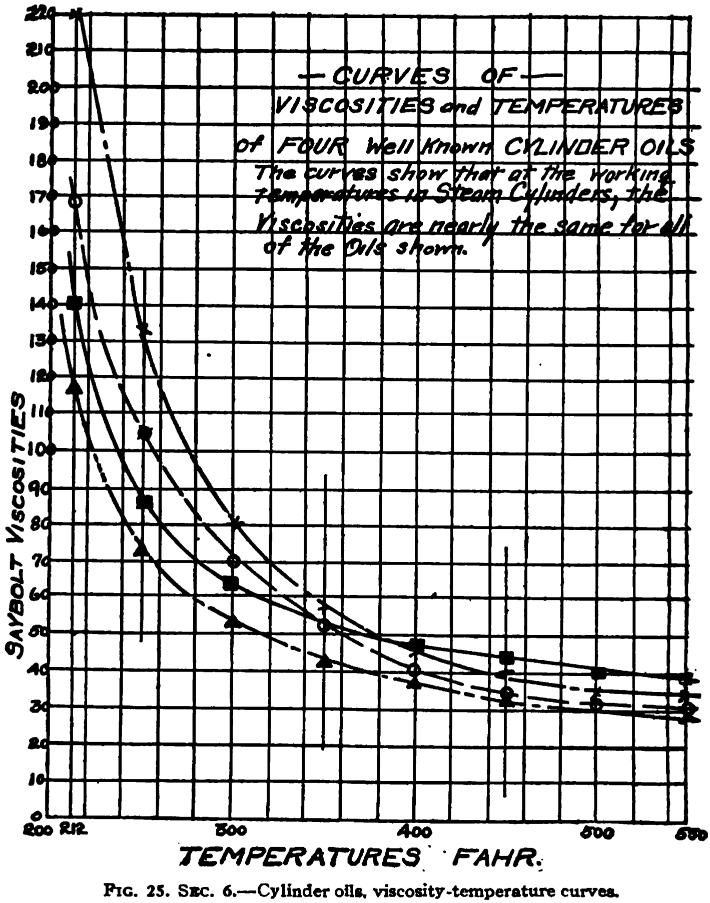

FIG. 25. SEC. 6.—Cylinder oils, viscosity-temperature curves.

freely flow into the bearing. With better circulation, the oil was able to balance the production of frictional heat by carrying it away as fast as it was created.

This illustration shows the necessity of using viscosity values, not as a direct guide to the selection of a lubricant, but as an indirect guide. The method of selection of an oil from its viscosity characteristics must

be based upon the temperature at which the oil will be expected to work, which in the case of a bearing will be the normal working temperature of the bearing. At this working temperature the viscosity of the oil should fulfil the mechanical and lubricating requirements of the bearing.

By plotting the viscosity-temperature curve of an oil, this selection may be simplified and comparisons made quickly with other oils. An example of the practical use of this method is given as follows:

"Assume an engine bearing to have a normal running temperature of 105° Fahr. when the engine-room temperature is 85°. In this case certainly no heat will pass from the air into the bearing. With the exception of the small amount of heat carried away by the engine frame, the 20° excess temperature is a measure of the frictional heat developed in the bearing, and this frictional heat is a measure of wasted energy. If an oil is selected, by means of its viscosity curve, produced from the same crude and having the same viscosity at 85° Fahr. that the oil in use has at 105° Fahr., the friction in the bearing will be reduced, because there will be no necessity for the viscosity of the second oil being reduced to meet the mechanical requirements of the bearing."

It is by far the most efficient practice to use an oil having the lowest viscosity that will insure the maintenance of the lubricating film in a bearing, and excessive viscosity is as much to be avoided as an insufficient supply of oil.

THE VALUE OF VISCOSITY IN STEAM CYLINDER LUBRICATION.—In the case of steam cylinder lubrication, the viscosity tests of cylinder oils have very little bearing upon the actual lubricating value of the oil.

It has become the custom of engineers and chemists to compare the viscosities of cylinder oils at a temperature of 212° Fahr. (by some at 210° Fahr.). A viscosity at this temperature is totally useless as an indication of the lubricating value of the oil, since no cylinder oil is ever called upon to work at this low temperature. Steam at only 75 pounds pressure has a temperature of 320° Fahr., while at the usual pressures the temperatures are much higher, as follows:

125 pounds to the square inch	353° Fahr.
150 pounds to the square inch	366° Fahr.
225 pounds to the square inch	397° Fahr.

As can be observed by reference to the curves of viscosities and temperatures of the typical cylinder oils, all of these curves approach a common viscosity as their temperatures are increased. At a temperature of 212° Fahr. their viscosities were widely different, but at 400° Fahr. they were only about 15° apart, and from 400° upwards the viscosities of practically all cylinder oils are the same. The viscosity of a cylinder oil has some bearing upon the rapidity and completeness of atomization of the oil by the incoming steam, but this is more or less of a mechanical action, taking place between the oil and the steam, and is effected largely by the apparatus for introducing the oil into the steam line.

TESTS FOR ANIMAL OIL COMPOUNDS

METHODS.—A rough test to determine the presence of animal oils in compound with mineral oils may be made as follows: Heat the oil in a small glass or test tube with a small amount of caustic soda, or caustic potash for 15 minutes. The presence of animal oil will be shown by a jelly-like solidification or by a foaming at the surface.

A quick method of detecting animal oils is to place a few drops of the oil on the palm of the hand and to rub it briskly with the other hand. The heat produced will cause the animal oil to smell if present.

For other tests for animal or vegetable oils see "Oil Analysis," by Augustus H. Gill, page 44.

THE COMMITTEE ON STANDARDIZATION OF PETROLEUM SPECIFICATIONS GIVE THE FOLLOWING TEST METHOD FOR FATTY OIL, VIZ.:

Solutions required:

(*a*) Approximately half-normal alcoholic potassium hydroxide. Dissolve 33 grams of potassium hydroxide sticks (or an equivalent amount of sodium hydroxide sticks) in 1000 c.c. of purified 92–95 per cent. ethyl alcohol. Allow to settle and filter.

(*b*) Purified benzene. This may be prepared as follows: To 1000 c.c. of "90 per cent. benzol" add a stick of sodium hydroxide, boil for an hour, using a condenser loop inside the neck of the flask. Transfer to a large separatory funnel and add sufficient water to cause the liquid to separate into two zones. Draw off the lower zone and discard. Wash the benzene with water once. Transfer the washed benzene to an Engler distillation flask and distill up to 82° C., discarding the residue.

(*c*) Standard solution of half-normal hydrochloric acid.

(*d*) Phenolphthalein Indicator. Dissolve 1 gram of phenolphthalein in 100 c.c. of 95 per cent. ethyl alcohol.

(*e*) Neutral gasoline.

Saponification:

Weigh 10 grams of oil into a 350 c.c. Erlenmeyer flask. Add from a pipette 30 c.c. of the alcoholic potassium hydroxide solution, followed by 25 c.c. of the purified benzene (C_6H_6). Connect with a condenser loop. Boil on steam bath or electric hot plate for 90 minutes, shaking occasionally. Remove and add 25 c.c. of neutral gasoline, and titrate with the half-normal hydrochloric acid solution, after adding 2 or 3 drops of the phenolphthalein indicator solution until the pink color is destroyed. The absence of the pink color may be determined after the titration has begun, by allowing the solution to stand at rest approximately a minute, and noting the color of the lower zone. Run two blanks with the same mixture of alcoholic potassium hydroxide solution and purified benzene. From the difference between the number of cubic centimetres of half-normal acid required for the blanks and for the determination, the percentage of fatty oil may be calculated as follows:

$$\frac{\text{No. of c.c. N/2 acid used} \times .02805 \times 100}{195 \times \text{weight of oil taken}} = \text{per cent. of fatty oil.}$$

$$\frac{2.8050}{1150}$$

ACIDITY TESTS

Certain kinds of engine and machine oils are treated with sulphuric acid during the process of refinement. In order to protect the highly polished surfaces of bearings, the lubricating oils used should be examined for acid that may have remained in the oil, due to improper refinement.

An easy test for sulphuric acid is to thoroughly wash a sample of the oil with warm water. Then test the water with neutral litmus paper, and if even a faint reddish tint is shown on the paper the oil should be rejected. A very small amount of acid will do a large amount of damage to a highly polished surface.

The percentage of acid in any lubricating oil should never exceed three-tenths of 1 per cent.

A properly refined lubricating oil should show no traces of sulphuric acid.

A simple boiler-room test for acid may be made by immersing a piece of highly polished copper in the oil for twenty-four hours. There should be no change in the brightness of the polished surface. If a trace of acid is present, the surface of the copper will be dulled.

Barium Chloride Test.—Another good test for sulphuric acid can be made by preparing a saturated solution of barium chloride in distilled water. Dilute an ounce of the oil with an equal quantity of high-gravity gasoline to make it more limpid and add six or seven drops of the barium chloride solution. If any sulphuric acid is present, a white deposit or precipitate will be formed.

FREE FATTY ACIDS.—Free fatty acids may exist in the fatty oils used for compounding with mineral oils. They are due to decomposition of the oils during storage in a crude state. Due to their action upon metal, these acids form soaps, which dissolve in the oil.

All vegetable and animal oils contain free fatty acid. The percentage may run from 0.5 per cent. up to or beyond 60 per cent. (See index for further data.)

BEHAVIOR OF FREE FATTY ACIDS IN LUBRICANTS.—(*Engineering*, vol. 108, No. 2814, Dec. 5, 1919, p. 758): Free fatty acids have always been considered injurious to lubricants, because they corroded and formed soaps, thickening the lubricant in the presence of moisture. In a discussion of the subject of "Oils as Lubricants," before the Physical Society, London, Eng., it was brought out that Southcombe found that a very restricted amount of fatty acid had a remarkable effect; where, owing to the shape and condition of the bearing surfaces, low speed, high pressure or inadequate oil supply, the oil film could not form completely, or became broken, permitting the solid surfaces to come into contact. Experimenting with a Thurston Friction Machine, at low speed, 7 feet per minute and a pressure of 270 pounds per square inch, Mr. Archbutt found that 1 per cent. of the fatty acid of rape oil added to a mineral lubricant, lowered the coefficient of friction from 0.0047 down to 0.0033 and that 2 per cent. of the acid did not effect any further lowering. When neutral rape oil was used, 60 per cent. was required to produce the same effect. Apparently a small percentage of fatty acid improved the lubricating value of a mineral oil as much as a large percentage of fatty oil. He also found that a perfectly neutral rape oil gave lower friction than a mineral oil of

the same viscosity. In comparative tests made with a commercial rape oil of 2.4 per cent. fatty acid R, and with a perfectly neutral oil R_1, prepared from R, and with a mineral oil M of the same viscosity, he obtained the following friction coefficients: $M = 0.0078$, $R = 0.0050$, $R_1 = 0.0045$.

The article states that, "If these results are confirmed, they suggest that the oiliness or lubricating efficiency of the unsaturated molecules of the neutral rape oil was nearly as great as that of the free fatty-acid molecules, but that the acid molecules were much more active in their influence on the hydrocarbon molecule of the mineral oil."

ORGANIC ACIDS.—These acids exist naturally in some petroleum crudes, and tests for them must be made by the oil chemist.

Holde states, that in dark, unrefined mineral oils, small quantities of weak organic acids, which may amount to 0.3 per cent., expressed as SO_3, or 2.1 per cent., expressed as oleic acid, may exist.

FREE ACID.—(Test methods, U. S. Div. Military Aeronautics, acknowledgment A. S. T. M.) Accurately weigh 5 grams of a compounded oil or a pure fixed oil into a flask, add 25 c.c. of 95 per cent. alcohol, which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with a tenth normal alkali free from carbonate, the solvent consisting of water and alcohol in the proportions of 1:5, using phenolphthalein or alkali blue, 6_h, as an indicator, agitating thoroughly after each addition of alkali. Follow the same method for mineral oils, excepting the alcohol, which should consist of equal proportions of distilled water and 95 per cent. alcohol. In titrating dark-colored mineral oils, the end reaction is better observed when alkali blue 6_h is used as the indicator.

Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 gram of fat or oil).

One c.c. of tenth normal alkali = 0.0282 gram of oleic acid. Alkali, 1 c.c. of which is equivalent to 0.00996 g. KOH, and 1 c.c. of which is equivalent to 1/2 per cent. oleic acid, may be used.

ACIDITY, TEST FOR.—(A. S. T. M. Method D47–18, printed by Committee on Standardization of Petroleum Specifications, April, 1920):

Accurately weigh 10 g. of the oil into a flask, add 50 c.c. of 95 per cent. alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein, alkali blue or turmeric as an indicator, agitating thoroughly after each addition of alkali. To express results as percentage oleic acid, use following equation:

One c.c. of tenth-normal alkali = 0.0282 gram of oleic acid. Alkali, 1 c.c. of which is equivalent to 0.5 per cent. of oleic acid, may be used.

CORROSION TEST.—(Committee on Standardization of Petroleum Products, April, 1920): A clean strip of pure copper about 1/2 in. wide and 2 ins. long is heated to redness in a Bunsen flame, and while red hot dropped into alcohol. Strip then allowed to dry as quickly as possible in the air and dropped into sample of the oil contained in a test tube. About half the length of copper strip should be submerged. Test tube is then closed with a stopper and left to stand 24 hours. At the end of this time copper strip is removed and washed clean with proper solvents. It is then compared with a similar strip freshly cleaned as previously described. No discoloration of the test strip should be shown by this comparison.

VOLATILITY TESTS

BOILING POINT RANGE (VACUUM DISTILLATION).—C. W. Stratford, in *The Aerial Age Weekly*, Vol. 7, No. 1, p.. 48, gives the following description and drawing: "The apparatus for making this test consists of a special steel still and vapor tower, a special water-cooled condenser and a chamber for the distillate receivers. * * * The distillation system is connected with a pump capable of maintaining a vacuum of 2 1/2 mm. absolute and having a capacity of 6 cubic feet per minute. The still is charged with 2000 c.c. of the oil under examination. The standard vacuum, 40 to 50 mm. absolute, is established throughout the closed system and heat applied to the bottom of the still." * * * Referring to the testing of airplane motor oils, Mr. Stratford says: "For the purpose of this specification, it will be necessary to carry the distillation only to the point at which the still temperature has reached 300°

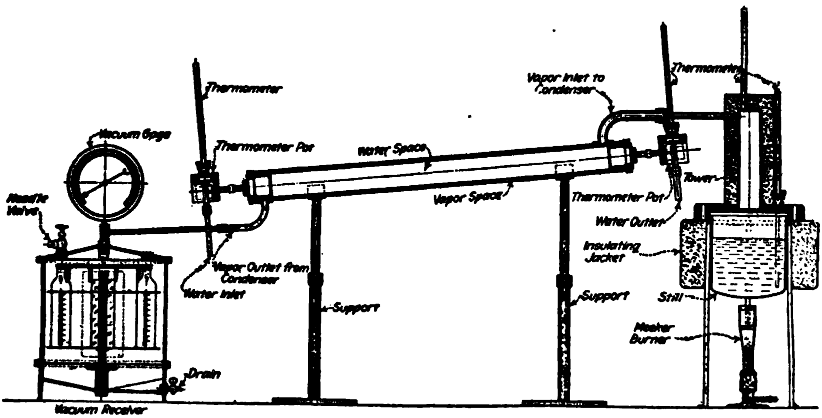

FIG. 26. SEC. 6.—Cross-section of vacuum distillation apparatus, showing receiver, still and other parts.

C. (572° Fahr.). The percentage of distillate up to 300° C. has been arbitrarily chosen as the basis for judging the relative volatility of various lubricating oils. However, for ultimate analysis, the distillation may be carried up to the point where nine-tenths of the total charge will have passed over, the rest being allowed to remain in the still and estimated as residual."

Mr. Stratford states that the quantity of the low boiling-point fractions varies widely in lubricating oils intended for use in different types of internal-combustion engines. He says that there should be a limit to the percentage of low boiling-point fractions, for the reason that too large a quantity will increase the specific consumption of the lubricant in service. He finds that an analysis of the most successful automobile oils indicates that not over 30 per cent. of the oil should distil over below 300° C. in the vacuum distillation apparatus shown below in Fig. 26, Sec. 6. The value of the test is that it indicates the specific consumption of the lubricant, the degree of lubrication, and the extent of carbonization of the oil when in the engine cylinders.

TEST FOR TARRY AND OTHER RESIDUES

If it is desirable to test a cylinder oil for tarry residues, the following method may be used:

Dissolve 5 c.c. of the oil in 95 c.c. of 86° gravity gasoline. Allow the mixture to stand for one hour, and the tar and other insoluble matter will collect at the bottom of the test tube.

Fig. 27. Sec. 6.—Centrifuge for determining percentage of tarry matter in heavy oils.

TESTS FOR TARRY MATTER.—The usual test for tarry matter is made by thoroughly shaking and then centrifuging in a special tapered graduate 5 per cent. of the oil and 95 per cent. petroleum ether. Fig. 27, Sec. 6, shows a centrifuge. The amount of sediment is read. A well-refined petroleum engine oil should show no sediment. A satisfactory cylinder stock should not show more than a very small percentage of tarry matter.

PRECIPITATION TEST.—(Committee on Standardization of Petroleum Specifications, April, 1920):

Five c.c. of the oil is mixed with 95 c.c. of petroleum ether in a tall, stoppered graduated cylinder and allowed to stand. The petroleum ether must be freshly redistilled and the portion boiling above 150° F. discarded. It must not show perceptible solubility in concentrated sulphuric acid.

EVAPORATION TEST

To make an evaporation test of an engine oil, a small quantity of the oil is placed in a shallow dish and carefully weighed. The dish is then exposed to a temperature of 212° Fahr. for four hours, after which it is weighed again. No engine oil should show a loss of more than 1/4 to 1/2 per cent. A good cylinder oil, when subjected to a temperature of 400° Fahr. for 24 hours, will not lose more than 2 per cent. in weight.

When specifying the method of conducting an evaporation test, the size of the dish in which the oil is to be tested must be given, in order to make the results obtained of any practical value for comparative purposes. The material of which the dish is made should be stated, and the method of heating the oil, whether in an oven or by steam, must also be known. It is generally best to specify the kind of oven.

The evaporation test of an oil is affected by barometric pressure, and in some cases there will be as much as a 1 1/2 per cent. variation in the results upon the same oil, when taken in different places having considerable difference in barometric pressure.

The most important result, from a practical standpoint, that is obtained from a cylinder oil evaporation test, is the nature and condition of the residue remaining at the end of the test. The percentage of evaporation does not have an important bearing upon cylinder lubrication. The most suitable cylinder oil is the one having a greasy, limpid residue. Any cylinder oil having a sticky, tough residue should be rejected, as such an oil will tend to produce deposits in steam cylinders and give unsatisfactory results.

A method used to determine the percentage of an oil of the spindle type which will become volatile on exposure is described by Gill, "Oil Analysis," p. 36: "Roughly, the method consists in weighing a water glass carrying a piece of filter paper of standard dimensions and then dropping onto the paper 0.2 gram of the oil. A constant temperature (140°–150° F.) air bath is passed around the water glass for eight hours, after which the watch glass is reweighed and the loss in weight figured in per cent." The test is a valuable guide to fire insurance companies, being an indication of the liability of the oil causing and spreading fire.

EVAPORATION TEST.—(Committee on Standardization of Petroleum Specifications, April, 1920):

Twenty grams of the oil is placed in a weighed, flat-bottomed glass crystallizing dish having a diameter of approximately 3 3/4 inches. The dish is then placed in an oven at a temperature of 212° F. for two hours, cooled in a desiccator, and weighed.

ASH.—(Test methods U. S. Div. Military Aeronautics, acknowledgments A. S. T. M.) The ash of any oil free from water may be determined by weighing 10 grams in a tarred dish, heating until it begins to smoke, igniting it with a flame and allowing it to burn quietly. When nothing but a charred mass remains, slightly tilt dish, apply gas flame to bottom and continue heating until the carbon is completely burned off. Cool in a desiccator and weigh. Maximum in dark cylinder oils is 0.080 per cent., minimum 0.002 per cent. If required, analyze chemically in the usual way.

COLOR VALUES

COLOR VALUES OF OILS.—The petroleum refiner takes the color values of oils into consideration as a check on correct processing. Color alone is no indication of purity. Change of color on heating is an indication of correct refining. The color values of oils are determined by comparison, in a tintometer, with standard chromate solutions or colored glasses. The Lovibond tintometer is widely used in the United States. Color values are given for oil containers or cells of different lengths. Short cells are used for dark oils and long cells for light-colored oils. The tests are reported as, for instance, 200/6", which means that the oil sample has an arbitrary value of 200 when viewed through a 6" cell.

FIG. 28. Sec. 6. Saybolt chromometer.

The color of oils by reflected light can be used to identify the crude base from which the oil was made. The oil sample is exposed to the reflected rays of strong sunlight or ultraviolet rays from an arc in a quartz lamp. Robin-egg-blue tints indicate Gulf Coast crudes. Violet tints indicate paraffin-base crudes. Oils of low viscosity usually show the most brilliant colors.

Fig. 28, Sec. 6, shows a Saybolt Chromometer, which is an instrument designed for color determination of oils. The cut shows the two tubes with a prismatic eye-piece, bringing both tubes into single eye vision. One tube is empty and a colored glass is located at the bottom as a standard. The other tube bears a graduated scale and is filled with the oil under examination. A mirror reflects the color at the bottom. To operate, the oil is slowly drained, and as the height of the oil column decreases the color lightens. When the color, as reflected up through the oil in tube, is the color reflected up through the colored glass, a reading is taken from the scale.

Fig. 29, Sec. 6, shows a Union Colorimeter as manufactured by the Union Petroleum Co., of Philadelphia, for determining the color of engine, machinery and cylinder oils, according to National Petroleum Association Standards, by comparison with standard color glasses as follows.

A, cylinder oil, extra light filtered; *D*, cylinder oil, light filtered; *E*, cylinder oil, medium filtered; *G*, lily white, N. P. A. No. 1; *H*, cream white, N. P. A. No. 1 1/2; *I*, extra pale, N. P. A. No. 2; *J*, extra lemon pale; *K*, lemon pale, N. P. A. No. 3; *L*, extra orange pale; *M*, orange pale, N. P. A. No. 4; *N*, pale; *O*, light red, N. P. A. No. 5; *P*, dark red, N. P. A. No. 6; *Q*, claret red.

The method of using this instrument is as follows: For lubricating oils, place a 4-oz. bottle of the oil under examination in one of the circular compartments of the instrument. In the opposite compartment place a 4-oz. bottle of water-white gasoline or distilled water. Then place one of the standard glasses in the slot and close the slide. The instru-

ment should then be taken to a window so that the observer on looking through can compare the color of the oil with the standard glass.

For filtered cylinder oil color determination the oil is first mixed with water-white gasoline in the proportion of 15 per cent. oil to 85 per cent. gasoline, and the same method as described for determining the color of the lubricating oils followed.

FIG. 29. SEC. 6.—Union colorimeter.

QUALITY TESTS.—A decision may be made as to whether an oil is well refined or not by the following test:

Fill a clean bottle half full of the oil under observation. Heat slowly over an open flame until vapors appear above the oil surface. Maintain the oil at this temperature for 15 minutes. If the oil is well refined, it will darken in color, but remain perfectly clear and free from sediment, after standing 24 hours, thus proving the absence of acid compounds.

Poorly refined oil will turn jet black under the above-described conditions, and after standing for 24 hours a black carbon-like deposit will appear, showing the presence of sulphuric or sulphonic acid compounds.

THERMAL CAPACITY OF LUBRICATING OILS

There have been some recent investigations made into the relation between the specific heat of an oil and its lubricating qualities with respect to its heat-absorbing properties.

* The specific heat of an oil is a measure of its thermal capacity; that is, the quantity of heat the oil must absorb to raise its temperature one degree Fahrenheit, as compared to the heat required to raise the same volume of water one degree Fahrenheit when at its maximum density.

The frictional heat developed in a bearing must be absorbed and carried away by the oil, or radiated from the bearing to the air, or conducted off by the engine frame. Claims have been made as to the relative merits of heavy and light oils with regard to their heat-absorbing qualities.

GUMMING TEST

GUMMING TEST.—The so-called "Gumming Test" for lubricating oils is of little practical value. Trouble due to gumming when using mineral lubricating oil is practically unknown, and the same may be said of evaporation tests.

* See page 154 for specific heat of petroleum.

OXIDIZATION

EFFECT OF HEATING OILS.—Holde (Mitth. kgl. techn. Versuchsenst., 11, pp. 261–272; J. Soc. Chem. Ind., 13, p. 668, 1894) states that the asphalt content of certain dark-colored lubricating oils before and after heating to 100° for ten hours was affected as follows: Oils with little or no asphalt originally remained liquid; those with 1.3 to 2.3 per cent. became thick and sticky; those with 5 to 6 per cent. were changed to a thick resinous-like mass. He also shows that the gumming is due not only to the concentration of asphalt as the oil evaporates, but also to a partial oxidation of the oil.

Schreiber (Zs. angew. Chem., 23, pp. 99–103, 1910) reports: When cylinder and compressor oils of various kinds were heated in a specially constructed air bath through which a current of air, carbon-dioxide or steam was passed, the tests ranging from 16 to 24 hours and the temperatures from 200° to 280°, the percentages of asphaltic material insoluble in benzine and in alcohol-ether were greatly increased in the case of air, and also in the case of carbon dioxide, but were practically unchanged when the oil was heated in the presence of steam.

OXIDIZATION OF MINERAL OILS.—Hirch, in the *Chemische Zeitung,* 19, p. 41, 1895, states that "notwithstanding conflicting statements, it is well established that mineral oils oxidize when raised to moderately high temperatures in the air. They may also oxidize at ordinary temperatures when exposed to sunlight, especially in the presence of alkalies."

DATA ON OXIDATION OF AUTOMOBILE CYLINDER OILS.—(C. E. Waters, Tech. Paper, Bur. Standards, 73): "It was shown that when an oil is oxidized in the sunlight some water and carbon dioxide are given off. The oil becomes highly acid and an insoluble oxidation product is thrown down, sometimes after only a few hours' insolation." * * * The paper reports the results in the changes in weight, percentage of carbonization due to oxidation and the acidity of three test oils exposed to the sunlight and air. The test as described used three oils:

Pensky-Martens closed cup	Oil No. 1	Oil No. 2	Oil No. 3
Flash point	215°	210°	205°
Fire point	270°	260°	250°

The paper states: "In order to follow the changes in weight of the oils under investigation, seven 10 g. portions of each were placed in 150 c.c. Erlenmeyer flasks, the mouths of which were covered with filter paper to exclude dust. On every bright day, for a total of 438 hours, they were placed outside a window facing south. * * * All weighings were made against a tare. * * * The following table gives the average gains in weight for the three oils at approximately equal intervals:

AVERAGE GAIN IN WEIGHT OF OILS EXPOSED TO SUNLIGHT AND AIR

(Tech. Paper No. 73—Bur. Standards. C. E. Waters)

Total exposure	Oil No. 1	Oil No. 2	Oil No. 3
	Milligrams	*Milligrams*	*Milligrams*
9 hours	9.1	19.3	18.2
51.5 hours	62.6	79.7	75.5
90 hours	88.0	107.7	104.0
130 hours	123.5	141.7	139.2
167.5 hours	154.0	170.9	169.6
205 hours	172.6	188.8	188.2
249 hours	180.7	197.4	197.0
289 hours	195.4	212.7	212.6
327 hours	210.5	227.2	227.2
364 hours	220.4	237.8	237.4
402 hours	229.9	247.4	246.7
438 hours	236.2	252.9	252.1

37 to 39 mm. high, with cover, without delivery tubes and one opening closed.

(*c*) Wrought-iron crucible with cover, about 180 c.c. capacity, 80 mm. diameter, 58 to 60 mm. high; about 10 mm. of sand placed in bottom to bring Skidmore crucible nearly flush with top.

(*d*) Triangle, medium size, pipe-stem covered, projection on one side to allow flame to reach all sides of the crucible.

(*e*) Sheet iron or asbestos hood, 5 inches in diameter and 2 inches high, provided with slanting roof 3/4 inch high, terminating into chimney, the chimney being 2 inches high and 2 1/8 inches to 2 1/4 inches in diameter. This serves to distribute the heat uniformly.

(*f*) Asbestos or sheet-iron block, 6 to 7 inches square and 1 1/4 to 1 1/2 inches high, provided with opening in centre, which is 3 1/4 inches in diameter at the bottom and 3 1/2 inches in diameter at the top of the block. This block acts as a shield for the flame, resulting in even distribution of the flame around the iron crucible during the test.

(*g*) Tripod. Tripod or stand should be of such height that the distance between the top of the burner and the bottom of large iron crucible is 1 inch to 1 1/2 inches, depending upon the kind of burner used.

(*h*) Gas burner. Where gasoline or artificial gas is used, the Maker or Scimatco burner, 155 mm. in height, having 24 mm. section of flame, is recommended. With natural gas, the above burners or any improved form of Bunsen burner may be used.

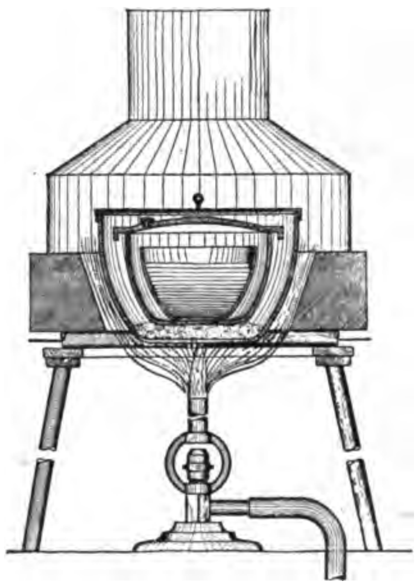

FIG. 30. SEC. 6.—Apparatus for Conradson carbon residue test.

Method: Weigh 10 grams of oil to be tested into a tared porcelain crucible and place the latter in the centre of the Skidmore crucible. Place the Skidmore crucible in the exact centre of the iron crucible, and put on the covers of the Skidmore crucible and iron crucible. Set the apparatus up as indicated in Fig. 1.

Heat is applied to the apparatus with a Bunsen or other burner with a hot flame for from 4 to 7 minutes, depending upon the body of the oil being tested; this flame should encompass, so far as possible, the whole crucible. It must then be reduced to 2 to 3 inches and the first appearance of vapors carefully watched for after the period of strong heating is over in order that the vapor flame does not get too high and the oil in the crucible is not in danger of boiling over. The flame should never get more than 3 inches above the chimney, and it should be kept at an average of about 2 inches above it during the period in which vapors come off. After the vapors cease to be evolved (as evidenced by the inability to

ignite them) the heat is increased to a maximum obtainable, and maintained for 5 minutes. The bottom of the iron crucible should be red hot; allow to cool for 5 minutes with the chimney removed; transfer the crucible to a desiccator, cool and weigh. The entire procedure should be completed within about 30 minutes, depending upon the nature of the oil.

Precautions: 1. The first appearance of vapors must be watched for very closely; the burner may be momentarily removed occasionally to facilitate seeing them. From experience, the range of 4 to 7 minutes with a Bunsen or Tirril burner appears to be about right for oils varying between a gun oil and a Liberty aero oil, but this time will vary with the gas and burner obtainable. It is, therefore, necessary that very close attention be paid to the operation at this point.

2. If the vapors get too high at any time the burner may be removed for short periods, although this is not advisable if it can be reduced sufficiently low to keep the vapors ignited about 2 inches above the chimney.

3. Dimensions of the apparatus as shown must be strictly adhered to.

CARBON TESTS ON INTERNAL-COMBUSTION ENGINE OILS, NEW AND USED.—(Abstracted from Liberty Aero Oil Report, U. S. Div. Military Aeronautics): Carbon residue tests by the Conradson Method, as well as carbonization values by the Waters' Test, both show lower values for new oils than for the same oils after use in internal-combustion engines. The following data are for oils from both the asphalt- and paraffin-base crudes, showing the effect of use in an internal-combustion engine upon the carbon tests of the several oils:

Oil	A		B		C		D	
	New	Used	New	Used	New	Used	New	Used
Baumé Gravity...	26.73	26.53	21.33	21.60	17.68	17.90	27.13	27.09
Flash (F. °).......	460	212	396	198	388	222	440	225
Pour Test (F. °)...	50	44	9	25	20	9	52	25
Vis. Say. at 100° F.	1744	1416	1447	1108	1223	1003	1340	1216
Vis. Say. at 130° F.	696	587	407	408	398	351	549	510
Conradson *Carbon Percent	1.63	2.06	1.45	1.84	.35	.80	1.00	1.46
Conradson *Carbon Nature	Hard	Hard adhesive	Loose flaky	Hard adhesive	Crusty	Hard adhesive	Loose flaky	Hard loose
*Waters Carbon...	Trace	.08	.52	1.21	1.18	1.49	Trace	.23
Residue Volume...	....	24%	....	22%	....	22%	....	22%
Residue Weight...	....	.25%	....	.59%	....	.41	....	.35

* (The above tests were obtained from samples of the oils taken from the same engine, and the tests were the same length and under the same conditions for each of the oils. It will be noted that the carbonization values by the Waters' method for the low Baumé oils (asphalt base) are higher than for the high Baumé (northern base) oils.

In general, for oils of the same classification as to crude source, the carbon content Conradson is directly related to the viscosity of the oil at 212° F., while the carbonization values by the Waters method is inversely related to the viscosity at 212° F.)

CARBONIZATION TESTS

WATERS' CARBONIZATION METHOD.—The following tests were obtained from typical oils from the crudes as indicated, and manufactured for the purpose of the lubrication of internal-combustion engines:

TYPICAL CARBONIZATION TESTS (WATERS' METHOD)

Source of crude	Nature base	Approximate tests	Carbonization value (Waters' method)
(1) California...	Asphalt base	22° Grav. Bé. 350° Flash Fahr. 200 Vis. Say. at 100° F. 0° Fahr. C. T.	0.31
(2) Pennsylvania	Paraffin base	30° Grav. Bé. 440° Fahr. flash 385 Vis. Say. at 100° F. 35° Fahr. C. T.	0.05
(3) Pennsylvania	Paraffin base	Filtered cylinder stock 26° Gravity Bé. 550° Flash, Fahr. 150 Vis. Say. at 212° F. 26° Fahr. C. T.	0.01
(4) Blend of Pennsylvania and Mid-Continent	Blend	26.0° Gravity Bé. 405° Flash Fahr. 335 Vis. Say. at 100° F. 35° C. T. Fahr.	0.18
(5) Texas.......	Asphalt base	21.6° Gravity Bé. 325° Flash Fahr. 315 Vis. Say. at 100° Fahr. 0° Fahr. C. T.	0.10
(6) Pennsylvania	Paraffin base blended cylinder stock	21.9° Gravity Bé. 363° Flash Fahr. 327 Vis. Say. at 100° Fahr. 25° Fahr. C. T.	0.38
(7) Pennsylvania	Paraffin base cylinder stock	26.6° Gravity Bé. 510° Flash Fahr. 1,550 Vis. Say. at 100° Fahr. 120 Vis. Say. at 212° Fahr.	0.01

The results given by the Waters method are the differences between amounts of the sample insoluble in petroleum ether before and after oven treatment, these differences being reported as "carbonization."

The Waters Oil Carbonization Bath consists of a cubical copper box, covered with asbestos and provided with a special cover for holding oil flasks so that they are open to the outer air. At the bottom of the bath

is a heating element of michrome wire. Connected with the heating element is a mercury thermoregulator. Outside of the bath are resistance coils, lamps, and relay for regulating the heating current. The air in the bath is stirred by means of a four-bladed fan that is revolved. A sheet of brass screen above the bath prevents drops of condensed oil being flung into the flask by the propeller that runs the fan. Ten grams of oil are heated to 250° C. for 2 1/2 hours, then cooled and mixed with 50 c.c. of petroleum ether. Next day the precipitate is filtered off, washed free from oil, dried and weighed.

The petroleum ether insolubles may indicate the solid carbonaceous matter formed in the oil when exposed to heat, causing some decomposition. These insolubles may also indicate precipitation of colloidal carbon and improper refining.

IODINE NUMBER OR VALUE

This is defined as the percentage of iodine that will be absorbed by an oil under conditions outlined in standard tests. The two principal methods are Hanus method and Hubl's method.

IODINE VALUE.—(Test methods U. S. Div. Military Aeronautics, acknowledgments A. S. T. M.) The iodine value of an oil or fat is the measure of the amount of iodine chloride it will absorb. Its practical application is to distinguish the non-drying or saturated oils, which may be used as lubricants, from the drying, unsaturated ones, not suitable for that purpose, but which are of high value in painting. The following show the parts per 100 absorbed by familiar oils:

Linseed	160	to	202
Castor	80	to	91
Olive	76	to	95
Mineral lubricating oils	9.46	to	16.0
Paraffin wax	4.0		

Various processes for obtaining this value have been proposed, but for rapid determinations, Wiji's process is commended. Its readings compare favorably with the more elaborate methods. It is now possible to purchase a dependable solution of iodine monochloride in pure glacial acetic acid, or, if preferred, the solution can be prepared after instructions given in Archbutt and Deeley's "Lubrication and Lubricants." Excellent results have been obtained with the following:

Test Method

APPARATUS AND REAGENTS

Two hundred c.c. ground glass, stoppered bottles. Small homœopathic vials, for weighing out the samples. Acetic acid + iodine monochloride solution (J. T. Baker's). Tenth normal sodium thiosulphate solution, carefully standardized. Starch paste: Boil 1 gram of starch in 200 c.c. of water for 10 minutes and cool to room temperature. Ten per cent. solution of potassium iodide, free from iodate. Distilled water. Chloroform or carbon disulfid C. P.

PROCEDURE

(*a*) Weighing the sample: Weigh about 1/2 gram of fat or 0.25 gram of oil into a homœopathic vial that has been dried and heated in the desiccator. In the case of a drying oil which has a very high iodine value use from 1/10 to 2/10 gram. The homœopathic vial is carefully lowered into the glass-stoppered bottle and the oil dissolved by adding 10 c.c. of chloroform or carbon disulfid as desired. The oil may be completely dissolved by carefully agitating the bottle, making sure not to splash any of the solution up the side of the bottle. Twenty-five c.c. of the acetic acid and iodine monochloride (Wiji's) solution are then carefully measured into the bottle from a burrette. Allow the bottle to stand with occasional shaking for one hour. The excess of iodine should be at least 60 per cent. of the amount added. The bottle should be placed in the dark and shaken carefully every 5 or 10 minutes. At the expiration of 1 hour, 10 c.c. of the 10 per cent. potassium iodid solution are poured into the bottle and 100 c.c. of distilled water added, washing down any free iodine that may be noted on the stopper. Titrate the iodine with the sodium thiosulphate, which is added gradually, constantly shaking until the yellow color of the solution has almost disappeared. Add a few drops of starch paste and continue the titration until the blue color has entirely disappeared. Toward the end of the reaction stopper the bottle and shake violently, so that any iodine remaining in solution in the chloroform may be taken up by the potassium iodid solution.

(*b*) Standardizing the iodine solution by thiosulphate solution: At the time of adding the iodine solution to the fat, employ two bottles of the same size as those used for the determination for conducting the operation described above, but without the presence of any fat. In every other respect the performance of the blank experiment should be just as described. These blank experiments must be made each time the iodine solution is used. Great care must be taken that the temperature of the solution does not change during the time of the operation, as acetic acid and alcohol have very high coefficients of expansion, and a slight change in temperature makes an appreciable difference in the strength of the solution.

The following method is given to show the method of calculation:

Per cent. of iodine absorbed:

Weight of fat taken	0.250	gram.
Quantity of iodine solution used	40.0	c.c.
Thiosulphate equivalent to iodine	65.0	c.c.
Thiosulphate equivalent to remaining iodine.	40.00	c.c.
Thiosulphate equivalent to iodine absorbed.	25.0	c.c.
Per cent of iodine absorbed (25.0 × 0.012692 × 100) ÷ 0.250	126.92	

IODINE VALUES OF VARIOUS OILS.—The following tests were made to obtain the iodine numbers of various petroleum oils in connection with the development of an oil suitable for use as a vehicle for carrying an antiseptic which freed a large quantity of chlorine, and where the utmost care was required to obtain an oil which would absorb the smallest amount of the chlorine, and thus form a corrosive acid.

	Filtered neutral oil (Appalachian crude)	Filtered spindle oil (Appalachian crude)	Petrolatum oil (Appalachian crude)	Pale paraffin oil (Mid-continent crude)	Medicinal oil (highly treated and filtered) (water white) (Mid-continent crude)
Bé. Gravity ..	32.5–33.5	33.2–34.2	31.5–33.0	27	34.2
Flash	385–395° F.	355–365° F.	390–400° F.	330° F.	340° F.
Say. Viscosity at 100° F.	127–136	88–95	130–140	86–93	87
Cloud....	26–30° F.	26–36° F.	26–36° F.	Below 34° F.	———
Iodine number..	13.04	15.20	13.83	16.48	0.80 (Hanus)
Pour.....	......	......	......	......	22° F.

No. 0 U. S. P. Petrolatum	13.28
No. 2 Petroleum Grease	13.82
No. 5 Petroleum Grease	14.21
White Petrolatum	11.72

A mixture of 45 per cent. medicinal oil, same tests as above given, and 45 per cent. 130° melting-point refined paraffin wax and 10 per cent. white petrolatum gave a 2.36 iodine number.

EXPANSION

RATE OF EXPANSION OF LUBRICATING OILS AT HIGH TEMPERATURES.—According to the experiments and reports of H. W. Bearce and E. L. Peffer, of the Bureau of Standards, Washington, D. C., the following information in regard to the rate of change of density and volume of petroleum lubricating oils at high temperatures was obtained. (See Technologic Paper, Bureau of Standards, No. 77.)

	Change per degree Centigrade			
	19° to 25°	25° to 50°	50° to 75°	75° to 95°
Automobile cylinder oil	.00063	.00063	.00063	.00063
Same oil with 4½ per cent. paraffin added	.00072	.00063	.00064	.00063

The above data were obtained in order to determine the effect of dissolved paraffin on the rate of expansion of oil. The sample of automobile oil did not contain paraffin, and then a known amount of paraffin was dissolved in the oil to obtain the second sample.

It is seen that dissolved paraffin caused a marked degree of increase in the rate of expansion between 19° and 25° C., while at the higher temperatures the rate was not materially changed.

With further reference to the results obtained, the report states that it was found that on certain samples the rate of change of density is practically the same at all temperatures between 25° C. and 95° C., while on other samples there is a marked falling off in the rate of expansion at the higher temperatures. The investigators state the conclusion that the arrangement of the molecules of the liquid and the solid particles appear to be such as to prevent the same closeness of packing at the low temperatures that exists at the higher temperatures at which the solid particles have themselves become liquid. This arrangement has the effect of giving such a mixture an abnormally high rate of expansion at the temperatures below the point of solidification of the particles.

Bacon and Hamor in their work, "The American Petroleum Industry," state as follows: "The coefficient of expansion of Pennsylvania petroleum is 0.000840, and that of Russian oil is 0.000817; it may be said to decrease as the specific gravity rises, the exceptions which occur being attributable to the chemical nature of the oils."

The coefficients of expansion of a number of typical crude oils, as given by Bacon and Hamor from data prepared by Engler, are as follows:

Origin	Pennsylvania	Canada	West Virginia	Ohio	Eastern Galicia	Western Galicia
Coefficient of expansion × 1,000,000	840	843	839	748	813	775
Specific gravity × 1,000	816	828	841	887	870	885

COEFFICIENT OF EXPANSION OF OIL.—(Circular No. 57, United States Bureau of Standards, "United States Standard Tables for Petroleum Oils.") These tables include the following table for obtaining the volume that would be occupied by a quantity of oil of various specific gravities occupying unit volume (1 gallon) at the designated temperatures. (Example: If the observed specific gravity is .660 at 70° Fahr., one gallon of oil measured at 70° Fahr. will occupy a volume of .9925 gallon at 60° Fahr. The circular states that the headings "Observed Specific Gravity" and "Observed Temperature" signify the true indication of the hydrometer and the true temperature of the oil; that is, the observed readings corrected, if necessary, for instrumental errors.)

VOLUME THAT WOULD BE OCCUPIED AT 60° F. BY A QUANTITY OF OIL OF VARIOUS SPECIFIC GRAVITIES OCCUPYING UNIT VOLUME AT THE DESIGNATED TEMPERATURES

Observed temperature in ° F	Observed specific gravity								
	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690	0.700
	Volume at 60° F occupied by unit volume at various temperatures								
30	1.028	1.027	1.026	1.025	1.024	1.023	1.023	1.022	1.021
32	1.026	1.025	1.024	1.023	1.022	1.022	1.021	1.020	1.020
34	1.024	1.023	1.022	1.022	1.021	1.020	1.019	1.019	1.018
36	1.022	1.021	1.021	1.020	1.019	1.019	1.018	1.017	1.017
38	1.020	1.020	1.019	1.018	1.017	1.017	1.016	1.016	1.016
40	1.0190	1.0180	1.0175	1.0170	1.0160	1.0155	1.0150	1.0145	1.0145
42	1.0170	1.0160	1.0155	1.0150	1.0145	1.0140	1.0135	1.0130	1.0130
44	1.0150	1.0145	1.0140	1.0135	1.0130	1.0125	1.0120	1.0115	1.0115
46	1.0130	1.0125	1.0120	1.0115	1.0110	1.0110	1.0105	1.0100	1.0100
48	1.0110	1.0105	1.0100	1.0100	1.0095	1.0095	1.0090	1.0085	1.0085
50	1.0090	1.0090	1.0085	1.0085	1.0080	1.0080	1.0075	1.0070	1.0070
52	1.0075	1.0070	1.0065	1.0065	1.0065	1.0060	1.0060	1.0055	1.0055
54	1.0055	1.0055	1.0050	1.0050	1.0045	1.0045	1.0045	1.0040	1.0040
56	1.0035	1.0035	1.0030	1.0030	1.0030	1.0030	1.0030	1.0030	1.0025
58	1.0020	1.0020	1.0015	1.0015	1.0015	1.0015	1.0015	1.0015	1.0015
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	.9985	.9985	.9985	.9985	.9985	.9985	.9985	.9985	.9985
64	.9965	.9965	.9965	.9970	.9970	.9970	.9970	.9970	.9970
66	.9945	.9950	.9950	.9950	.9955	.9955	.9955	.9960	.9960
68	.9930	.9930	.9935	.9935	.9940	.9940	.9940	.9945	.9945
70	.9910	.9915	.9920	.9920	.9925	.9925	.9930	.9930	.9930
72	.9890	.9895	.9900	.9905	.9910	.9910	.9915	.9915	.9920
74	.9875	.9880	.9885	.9890	.9895	.9895	.9900	.9905	.9905
76	.9860	.9865	.9870	.9875	.9880	.9880	.9885	.9890	.9890
78	.9840	.9850	.9855	.9860	.9865	.9870	.9870	.9875	.9880
80	.982	.983	.984	.984	.985	.985	.985	.986	.986
82	.981	.981	.982	.983	.983	.984	.984	.985	.985
84	.979	.980	.980	.981	.982	.982	.983	.983	.984
86	.978	.978	.979	.980	.980	.981	.981	.982	.982
88	.976	.977	.977	.978	.979	.979	.980	.980	.981
90	.974	.975	.976	.977	.977	.978	.978	.979	.980
92	.973	.974	.974	.975	.976	.976	.977	.978	.978
94	.971	.972	.973	.974	.974	.975	.976	.976	.977
96	.969	.970	.971	.972	.973	.974	.974	.975	.976
90	.968	.969	.970	.971	.972	.972	.973	.974	.974
100	.966	.967	.968	.969	.970	.971	.972	.972	.973
102	.965	.966	.967	.968	.969	.970	.970	.971	.972
104	.963	.964	.965	.966	.967	.968	.969	.970	.971
106	.962	.963	.964	.965	.966	.967	.968	.968	.969
106	.960	.961	.962	.963	.964	.965	.966	.967	.968
110	.959	.960	.961	.962	.963	.964	.965	.966	.967
112	.957	.958	.960	.961	.962	.963	.964	.965	.966
114	.956	.957	.958	.959	.961	.962	.963	.964	.965
116	.954	.956	.957	.958	.959	.960	.961	.962	.964
118	.953	.954	.955	.957	.958	.959	.960	.961	.962
120	.951	.953	.954	.955	.957	.958	.959	.960	.961

(Taken from the United States Standard Tables for Petroleum Oils.) Circular No. 57, Bureau of Standards, 1st Edition, January 29, 1916.

VOLUME THAT WOULD BE OCCUPIED AT 60° F. BY A QUANTITY OF OIL OF VARIOUS SPECIFIC GRAVITIES OCCUPYING UNIT VOLUME AT THE DESIGNATED TEMPERATURES (Continued)

Observed temperature in °F	Observed specific gravity								
	0.710	0.720	0.730	0.740	0.750	0.760	0.770	0.780	0.790
	Volume at 60° F occupied by unit volume at various temperatures								
30	1.021	1.020	1.020	1.019	1.018	1.018	1.017	1.017	1.016
32	1.019	1.019	1.018	1.018	1.017	1.017	1.016	1.015	1.015
34	1.018	1.017	1.017	1.016	1.016	1.015	1.015	1.014	1.014
36	1.016	1.016	1.015	1.015	1.014	1.014	1.014	1.013	1.013
38	1.015	1.015	1.014	1.014	1.013	1.013	1.012	1.012	1.012
40	1.0140	1.0135	1.0130	1.0130	1.0125	1.0120	1.0115	1.0110	1.0105
42	1.0125	1.0120	1.0115	1.0115	1.0110	1.0105	1.0105	1.0100	1.0095
44	1.0110	1.0110	1.0105	1.0100	1.0100	1.0095	1.0090	1.0085	1.0085
46	1.0095	1.0095	1.0090	1.0090	1.0085	1.0085	1.0080	1.0075	1.0075
48	1.0080	1.0080	1.0075	1.0075	1.0070	1.0070	1.0065	1.0065	1.0060
50	1.0065	1.0065	1.0065	1.0060	1.0060	1.0060	1.0055	1.0055	1.0050
52	1.0055	1.0055	1.0050	1.0050	1.0050	1.0045	1.0045	1.0045	1.0040
54	1.0040	1.0040	1.0035	1.0035	1.0035	1.0035	1.0030	1.0030	1.0030
56	1.0025	1.0025	1.0025	1.0025	1.0025	1.0020	1.0020	1.0020	1.0020
58	1.0015	1.0015	1.0015	1.0015	1.0010	1.0010	.10010	1.0010	1.0010
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	.9985	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990
64	.9975	.9975	.9975	.9975	.9975	.9975	.9980	.9980	.9980
66	.9960	.9960	.9965	.9965	.9965	.9965	.9970	.9970	.9970
68	.9945	.9950	.9950	.9950	.9955	.9955	.9955	.9960	.9960
70	.9935	.9935	.9940	.9940	.9940	.9945	.9945	.9950	.9950
72	.9920	.9925	.9925	.9930	.9930	.9935	.9935	.9935	.9940
74	.9910	.9910	.9915	.9915	.9920	.9920	.9925	.9925	.9930
76	.9895	.9895	.9900	.9905	.9910	.9910	.9915	.9915	.9920
78	.9885	.9885	.9890	.9890	.9895	.9900	.9905	.9905	.9910
80	.987	.987	.987	.988	.988	.989	.989	.989	.990
82	.985	.986	.986	.987	.987	.988	.988	.988	.989
84	.984	.985	.985	.986	.986	.987	.987	.987	.988
86	.983	.983	.984	.984	.985	.985	.986	.986	.987
88	.981	.982	.983	.983	.984	.984	.985	.985	.986
90	.980	.981	.981	.982	.983	.983	.984	.984	.985
92	.979	.980	.980	.981	.981	.982	.983	.983	.984
94	.978	.979	.979	.980	.980	.981	.982	.982	.983
96	.976	.977	.978	.979	.979	.980	.981	.981	.982
98	.975	.976	.977	.977	.978	.979	.980	.980	.981
100	.974	.975	.975	.976	.977	.978	.979	.979	.980
102	.973	.974	.974	.975	.976	.977	.978	.978	.979
104	.972	.972	.973	.974	.975	.976	.977	.977	.978
106	.971	.971	.972	.973	.974	.975	.976	.976	.977
108	.969	.970	.971	.972	.973	.974	.975	.975	.976
110	.968	.969	.970	.971	.972	.973	.974	.974	.975
112	.967	.968	.969	.970	.971	.972	.973	.973	.974
114	.966	.967	.968	.969	.970	.971	.972	.972	.973
116	.965	.966	.967	.968	.969	.970	.971	.971	.972
118	.964	.965	.966	.967	.968	.969	.970	.970	.971
120	.962	.964	.965	.966	.967	.968	.969	.969	.970

VOLUME THAT WOULD BE OCCUPIED AT 60° F. BY A QUANTITY OF OIL OF VARIOUS SPECIFIC GRAVITIES OCCUPYING UNIT VOLUME AT THE DESIGNATED TEMPERATURES (Continued)

Observed temperature in ° F	Observed specific gravity								
	0.800	0.810	0.820	0.830	0.840	0.850	0.860	0.870	0.880
	Volume at 60° F occupied by unit volume at various temperatures								
30	1.016	1.015	1.015	1.014	1.014	1.014	1.013	1.013	1.013
32	1.014	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.012
34	1.013	1.013	1.013	1.012	1.012	1.012	1.011	1.011	1.011
36	1.012	1.012	1.011	1.011	1.011	1.011	1.010	1.010	1.010
38	1.011	1.011	1.010	1.010	1.010	1.010	1.009	1.009	1.009
40	1.0105	1.0100	1.0095	1.0095	1.0095	1.0090	1.0090	1.0090	1.0085
42	1.0095	1.0090	1.9090	1.0085	1.0085	1.0080	1.0080	1.0080	1.0075
44	1.0085	1.0080	1.0080	1.0075	1.0075	1.0075	1.0070	1.0070	1.0070
46	1.0075	1.0070	1.0070	1.0065	1.0065	1.0065	1.0065	1.0060	1.0060
48	1.0060	1.0060	1.0060	1.0060	1.0055	1.0055	1.0055	1.0050	1.0050
50	1.0050	1.0050	1.0050	1.0050	1.0045	1.0045	1.0045	1.0045	1.0045
52	1.0040	1.0040	1.0040	1.0040	1.0035	1.0035	1.0035	1.0035	1.0035
54	1.0030	1.0030	1.0030	1.0030	1.0025	1.0025	1.0025	1.0025	1.0025
56	1.0020	1.0020	1.0020	1.0020	1.0020	1.0020	1.0015	1.0015	1.0015
58	1.0010	1.0010	1.0010	1.0010	1.0010	1.0010	1.0010	1.0010	1.0010
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990
64	.9980	.9980	.9980	.9985	.9985	.9985	.9985	.9985	.9985
66	.9970	.9970	.9970	.9975	.9975	.9975	.9975	.9975	.9975
68	.9960	.9960	.9960	.9965	.9965	.9965	.9965	.9965	.9965
70	.9950	.9950	.9950	.9955	.9955	.9955	.9955	.9960	.9960
72	.9940	.9945	.9945	.9945	.9945	.9945	.9945	.9950	.9950
74	.9930	.9935	.9935	.9935	.9940	.9940	.9940	.9940	.9940
76	.9920	.9925	.9925	.9925	.9930	.9930	.9930	.9935	.9935
78	.9910	.9915	.9915	.9915	.9920	.9920	.9920	.9925	.9925
80	.990	.990	.990	.991	.991	.991	.991	.991	.992
82	.989	.989	.989	.990	.990	.990	.990	.991	.991
84	.988	.988	.989	.989	.989	.989	.989	.990	.990
86	.987	.987	.988	.988	.988	.988	.989	.989	.989
88	.986	.987	.987	.987	.987	.987	.988	.988	.988
90	.985	.986	.986	.986	.987	.987	.987	.987	.987
92	.984	.985	.985	.985	.986	.986	.986	.986	.987
94	.983	.984	.984	.985	.985	.985	.985	.985	.986
96	.982	.983	.983	.984	.984	.984	.984	.985	.985
98	.981	.982	.982	.983	.983	.983	.984	.984	.984
100	.980	.981	.981	.982	.982	.982	.983	.983	.983
102	.979	.980	.980	.981	.981	.982	.982	.982	.983
104	.979	.979	980	.980	.981	.981	.981	.981	.982
106	.978	.978	.979	.979	.980	.980	.980	.981	.981
100	.977	.977	.978	.978	.979	.979	.980	.980	.980
110	.976	.976	.977	.977	.978	.978	.979	.979	.979
112	.975	.976	.976	.977	.977	.978	.978	.978	.979
114	.974	.975	.975	.976	.976	.977	.977	.977	.978
116	.973	.974	.974	.975	.975	.976	.976	.977	.977
118	.972	.973	.973	.974	.974	.975	.975	.976	.976
120	.971	.972	.973	.973	.974	.974	.975	.975	.976

VOLUME THAT WOULD BE OCCUPIED AT 60° F. BY A QUANTITY OF OIL OF VARIOUS SPECIFIC GRAVITIES OCCUPYING UNIT VOLUME AT THE DESIGNATED TEMPERATURES (Continued)

Observed temperature in ° F	Observed specific gravity						
	0.890	0.900	0.910	0.920	0.930	0.940	0.950
	Volume at 60° F occupied by unit volume at various temperatures						
30	1.013	1.012	1.012	1.012	1.012	1.012	1.011
32	1.012	1.011	1.011	1.011	1.011	1.011	1.011
34	1.011	1.010	1.010	1.010	1.010	1.010	1.010
36	1.010	1.010	1.009	1.009	1.009	1.009	1.009
38	1.009	1.009	1.009	1.008	1.008	1.008	1.008
40	1.0085	1.0080	1.0080	1.0080	1.0080	1.0080	1.0080
42	1.0075	1.0075	1.0075	1.0070	1.0070	1.0070	1.0070
44	1.0070	1.0065	1.0065	1.0065	1.0065	1.0060	1.0060
46	1.0060	1.0060	1.0060	1.0055	1.0055	1.0055	1.0055
48	1.0050	1.0050	1.0050	1.0050	1.0050	1.0045	1.0045
50	1.0040	1.0040	1.0040	1.0040	1.0040	1.0040	1.0040
52	1.0035	1.0035	1.0035	1.0030	1.0030	1.0030	1.0030
54	1.0025	1.0025	1.0025	1.0025	1.0025	1.0025	1.0025
56	1.0015	1.0015	1.0015	1.0015	1.0015	1.0015	1.0015
58	1.0010	1.0010	1.0010	1.0010	1.0010	1.0010	1.0005
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	.9990	.9995	.9995	.9995	.9995	.9995	.9995
64	.9985	.9985	.9985	.9985	.9985	.9985	.9985
66	.9975	.9980	.9980	.9980	.9980	.9980	.9980
68	.9970	.9970	.9970	.9970	.9970	.9970	.9970
70	.9960	.9960	.9960	.9960	.9960	.9960	.9965
72	.9950	.9955	.9955	.9955	.9955	.9955	.9955
74	.9945	.9945	.9945	.9945	.9945	.9945	.9945
76	.9935	.9935	.9935	.9935	.9935	.9940	.9940
78	.9925	.9930	.9930	.9930	.9930	.9930	.9930
80	.992	.992	.992	.992	.992	.992	.992
82	.991	.991	.991	.991	.991	.991	.991
84	.990	.990	.990	.990	.990	.990	.991
86	.989	.989	.990	.990	.990	.990	.990
88	.988	.988	.989	.989	.989	.989	.989
90	.988	.988	.988	.988	.988	.988	.988
92	.987	.987	.987	.987	.987	.987	.988
94	.986	.986	.986	.986	.987	.987	.987
96	.985	.985	.985	.986	.986	.986	.986
98	.985	.985	.985	.985	.985	.985	.985
100	.984	.984	.984	.984	.984	.984	.985
102	.983	.983	.983	.983	.984	.984	.984
104	.982	.982	.982	.983	.983	.983	.983
106	.981	.981	.982	.982	.982	.982	.983
108	.981	.981	.981	.981	.981	.982	.982
110	.980	.980	.980	.980	.981	.981	.981
112	.979	.979	.979	.980	.980	.980	.981
114	.978	.978	.978	.979	.979	.979	.980
116	.977	.978	.978	.978	.978	.979	.979
118	.976	.977	.977	.977	.978	.978	.978
120	.976	.976	.976	.976	.977	.977	.978

EMULSIFICATION

Dr. Winslow H. Herschel, of the Bureau of Standards, who has done considerable work in developing tests to measure the resistance of an oil to emulsification, gives the following information on p. 23, B. of Stds. Paper No. 86, with reference to the theory of emulsification: "Various theories are discussed by Bancroft, but for the purpose at hand it will be sufficient to point out that milk, a natural emulsion, is composed of globules of butter fat coated with casein and suspended in water. In mayonnaise dressing, the globules of oil are coated with the yolk of egg and suspended in vinegar. The object of the pharmacist in making permanent emulsions is, first, to thoroughly divide the oil into globules and then to surround each globule with an adhesive envelope to prevent them from reuniting. The lubricating and industrial oil engineer, on the contrary, desires that there shall be no substance present in the oil which might form an adhesive envelope in case the oil became finely divided. In other words, if nothing is present but pure oil and pure water, any emulsion which may be formed has but little permanence."

TWO KINDS OF EMULSION.—Doctor Herschel further describes the two kinds of emulsions as follows: "It is well known that there are two kinds of emulsions, the first consisting of drops of oil in water, as in milk; the second, of drops of water in oil, as in the case of butter. Emulsions made by the pharmacist are of the first kind. * * *"

* DEMULSIBILITY

DEFINITION.—Herschel gives the following definition for demulsibility: "It is the maximum rate of settling out of an oil from an emulsion, in cubic centimetres per hour, when the emulsion is made and the rate of settling is found as follows: Twenty c.c. of oil and 40 c.c. of distilled water are placed in a 100 c.c. cylinder, having an inside diameter of 26 mm. and heated in a water bath to 55° C. The liquids are then stirred with a paddle for 5 minutes at a speed of 1500 R. P. M. The paddle is simply a metal plate 89 by 20 by 1 1/2 mm. submerged in the liquid. The cylinder is allowed to stand for an hour at a temperature of 55° C., and from each of the readings, taken as frequently as necessary, of the volumes of oil settled out from the emulsion, there is calculated the average rate of settling, between the time of stopping the paddle and the time of observation. The maximum rate of settling thus obtained is called the demulsibility, and is used as a measure of the resistance of the oil to emulsification. The maximum possible demulsibility, as the first reading is taken one minute after the paddle is stopped, is 1200.

Fig. 31, Sec. 6, shows a view of the emulsifier in use by the Bureau of Standards. The oil and water are placed in a graduated glass cylinder. A flat metal paddle, carried on a vertical shaft, is rotated by an electric motor. The speed is indicated by a liquid tachameter attached to the upper end of the motor shaft, and the speed control is obtained by means of a sliding rheostat. The glass cylinder is placed in the bath, consisting of a brass cup filled with water, and the bath is brought to the desired temperature by means of a Bunsen burner. One feature of the apparatus, not shown in the figure, is a false bottom to the bath, permitting a circulation of water below the cylinder.

"When an emulsion of oil and water is allowed to stand in a cylindrical glass vessel, there will usually appear sooner or later a fairly clear meniscus, between the emulsion and a layer above it, of oil which has separated out, and this meniscus will fall as the layer of oil increases in depth. Meanwhile a second less distinct layer, separating the emulsion from the water, will work its way up from the bottom of the vessel."

Doctor Herschel has given the following information to the author: The temperature of 130° F. was adopted to agree with recommendations of the A. S. T. M. for standard temperatures for viscosity tests, and the value of 55° C. is merely an approximation. (More accurately 54.4° C.) The value of 131° F. should not be used. (See Proc. A. M. Society for Testing Materials, Vol. 15, Part I, p. 280, 1915.) The width of the paddle was originally taken as 7/8 inch, * * * but was found that this width could be decreased, with an advantageous increase in the width of clearance, without changing the rate of settling which would be obtained. "The width as given above is about 13/16 inch," the length remaining the same.

Doctor Herschel further advises: "I do not stand sponsor for the statement * * * that my test can be used for splash feed, crank-case steam engine oils. I find that oils for use in 'crank-cases of Westinghouse steam engines' give a 'demulsibility' of zero. Perhaps the demulsibility would be even lower if the scale for demulsibility was so arranged that it would be possible to measure lower values."

* See index for test method outlined by Committee on Standardization of Petroleum Specifications, April, 1920.

The following rules are given by Doctor Herschel:

1. Care should be taken by shaking the container in which the oil is received and otherwise, that the oil which is used in the test is a fair sample.

2. If the oil is received in a glass bottle, care should be taken that it is not exposed to sunlight.

3. Care must be taken that cylinders and paddle are clean from one oil before testing another. After wiping the paddle with the finger, to

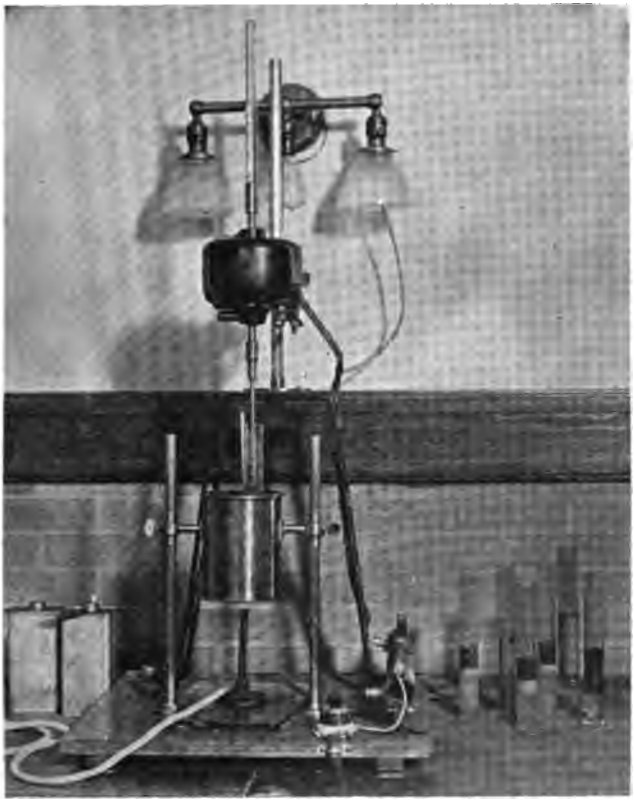

FIG. 31. SEC. 6.—Emulsifier in use at the Bureau of Standards.

avoid drainage losses, it should be wiped a second time with an absorbent body to avoid contamination of the fresh oil. If soap is used in cleaning the cylinders, especial care must be taken to eliminate all traces of soap in the final rinsing.

4. It is convenient, to save time, to adopt a rule that no oil shall be allowed to stand for a greater length of time than one hour, and take its demulsibility as the number of cubic centimetres of oil which have

settled out in that time. While there are some oils that do not reach their maximum rate of settling in one hour, they are of such poor quality that, when engine oils are being considered, it is not necessary to distinguish between them. Oils which show no signs of settling at the end of one hour are said to have zero demulsibility.

5. It is convenient and sufficiently accurate for most purposes to take readings only on even minutes and to the nearest cubic centimetre.

FIG. 32. SEC. 6.—Herschel emulsifier, designed by C. W. Stratford. (Courtesy Tide Water Oil Co.)

6. If rule 5 is adopted, the highest possible demulsibility will be obtained if all the oil—20 c.c.—settles out in one minute, or at the rate of 1200 c.c. per hour, and the demulsibility may be taken without calculation from the table preceding. If the scale of the cylinder were used which reads from the top down, the values in the first line of the table would run from 41 to 60, instead of from 59 to 40.

7. Much time can be saved in case it is not necessary to get the exact value of demulsibility, but only to find whether or not the demulsibility is up to a specified value. This is an advantage in comparison with other methods of test, which require that the emulsion must be set aside for an hour, 24 hours or other stated time. For example, if a demulsibility of 300 is specified and the oil has not all settled out in four minutes, it has failed to meet the requirements, and it is not necessary to wait until the maximum rate of settling has been reached, or until the end of an hour, to find perhaps whether the demulsibility is nearer 25 or to 30.

8. The object in expressing resistance to emulsification by a single numerical value is to be able to describe the desired quality of the oil in a manner which could be enforced in a contract. * * *

Fig. 32, Sec. 6, shows a Herschel Emulsifier, designed by C. W. Stratford for the Tidewater Oil Co.

Fig. 33, Sec. 6, shows the emulsion testing machine in use at the United States Naval Experimental Station at Annapolis, Md. It may be described as follows:

A suitable frame (2 inches by 2 inches by 1/4 inch) of angle iron is constructed as below, to hold the various parts. A tachometer is attached to the top of the frame and connected to the motor shaft. This indicates the speed of the motor. The motor is a direct-current shunt motor (1 ampère, 110 volts, 2400 R. P. M.), carrying on its lower shaft a set screw and rod. On the end of the rod is a flat paddle. (The paddle is 3 1/2 inches long by 7/8 inch wide and 1/16 inch thick.) The rod and paddle extend down into a glass, oil-and-water containing cylinder, or emulsion cylinder, graduated to 100 c.c. (1 1/4 inches in diameter and 11 inches high.) This graduated cylinder is supported on an iron frame, in a larger glass vessel (4 1/2 inches in diameter and 10 inches high), which provides the emulsion cylinder with a surrounding water bath.

FIG. 33. SEC. 6.—Emulsion testing machine. (U. S. Navy Academy.)

A rheostat, which is connected in series with the motor armature, can be adjusted to regulate the motor speed.

Brass clips are provided for holding the emulsion cylinder, and also a hook for holding a thermometer in the water bath for noting the temperature. A motor switch is attached to the upper part for the supporting frame.

EMULSION TEST.—(Test method U. S. Div. Military Aeronautics, acknowledgment A. S. T. M.) To determine whether or not new oils are sufficiently refined so that they may be purified in the reclaimer after use, they are submitted to the following simple emulsion test:

One ounce of oil shall be placed in the standard four-ounce sample bottle with one ounce of distilled water. The mixture shall be heated to a temperature of 180° F. and then shaken vigorously for five minutes. After

standing one hour at a temperature approximately 130° F., the oil must be clear and of the same color as before the test. All of the water must have settled and appear only slightly cloudy.

* RATE OF SETTLING OR DEMULSIBILITY OF OILS (EXPRESSED IN CUBIC CENTIMETRES PER HOUR)

Elapsed time after stirring, minutes	Reading at upper surface of emulsion, c.c.																			
	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	**40**
1......	60	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1020	1080	1140	**1200**
2......	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	**600**
3......	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	**400**
4......	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	**300**
5......	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	**240**
6......	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	**200**
7......	9	17	26	34	43	51	60	69	77	86	94	103	112	120	129	137	146	155	163	**172**
8......	8	15	23	30	38	45	53	60	68	75	83	90	98	105	112	120	128	135	143	**150**
9......	7	13	20	27	33	40	47	53	60	67	73	80	87	93	100	107	113	120	127	**134**
10......	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	**120**
11......	6	11	16	22	27	33	38	44	49	55	60	65	71	76	82	87	93	98	104	**109**
12......	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	**100**
13......	5	9	14	19	23	28	32	37	42	46	51	55	60	65	69	74	79	83	88	**92**
14......	4	9	13	17	21	25	30	34	39	43	47	51	56	60	64	69	73	77	81	**86**
15......	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	**80**
16......	4	8	11	15	19	23	26	30	34	37	41	45	49	53	56	60	64	68	71	**75**
17......	4	7	11	14	18	21	25	28	32	35	39	42	46	49	53	56	60	64	67	**71**
18......	3	7	10	13	17	20	23	27	30	33	37	40	43	47	50	53	57	60	63	**67**
19......	3	6	10	12	16	19	22	25	28	32	35	38	41	44	47	51	54	57	60	**63**
20......	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	**60**
21......	3	6	9	11	14	17	20	23	26	29	31	34	37	40	43	46	49	51	54	**57**
22......	3	5	8	11	14	16	19	22	25	27	30	33	35	38	41	44	46	49	52	**55**
23......	3	5	8	10	13	16	18	21	24	26	29	31	34	37	39	42	44	47	50	**52**
24......	3	5	8	10	13	15	18	20	23	25	28	30	33	35	38	40	43	45	48	**50**
25......	2	5	7	10	12	14	17	19	22	24	26	29	31	34	36	38	41	43	46	**48**
26......	2	5	7	9	12	14	16	18	21	23	25	28	30	32	35	37	39	42	44	**46**
27......	2	4	7	9	11	13	16	18	20	22	24	27	29	31	33	36	38	40	42	**44**
28......	2	4	6	9	11	13	15	17	19	21	24	26	28	30	32	34	36	39	41	**43**
29......	2	4	6	8	10	12	15	17	19	21	23	25	27	29	31	33	35	37	39	**41**
30......	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	**40**
35......	2	3	5	7	9	10	12	14	15	17	19	21	22	24	26	27	29	31	33	**34**
40......	2	3	5	6	8	9	11	12	14	15	17	18	20	21	23	24	26	27	29	**30**
45......	1	3	4	5	7	8	9	11	12	13	15	16	17	19	20	21	23	24	25	**27**
50......	1	2	4	5	6	7	8	10	11	12	13	14	16	17	18	19	20	22	23	**24**
55......	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	19	20	21	**22**
60......	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	**20**

EXPLANATORY NOTE.—The following examples illustrate the construction of this table: If the reading at upper surface of emulsion is 50 c.c. and the elapsed time is 15 minutes, the rate of settling or demulsibility $= (60 - 50) \times \frac{60}{15} = 40$ c.c. per hour; for a reading of 45 c.c. and a time of 10 minutes, demulsibility $= 60 - 45) \times \frac{60}{10} = 90$ c.c. per hour.

* Taken from Bureau of Standards Tech. Paper No. 86.

A more elaborate method for the same purpose is the one proposed by Dr. P. H. Conradson, in which the oil is exposed to the action of live steam. The apparatus required is a retort of any convenient form in which steam can be generated, or if steam of fairly pure quality is available this may be used. For oil containers, glass cylinders of rather tall form, graduated to 250 c.c. may be used. In carrying out the test, 20 c.c. of water is filled into the cylinder, and to this 100 c.c. of the oil to be tested are added. Steam is conducted to the bottom of the cylinder through either a glass or a metal tube, approximately 5/16 inch inside diameter, the lower end of which is cut off diagonally. Care should be used that the steam line has been drained of water before connecting up for making the test. The first action of the steam is to heat the mixture, and by the time it has reached 200° F. steam is actually passing off the mixture, and the experiment should be continued for 10 minutes after this time. Remove the cylinder to a water bath kept at a temperature of 130° F. At the expiration of one hour the cylinder is removed from the bath and the contents examined for the following:

1. The number of cubic centimetres of separate clear or turbid water.
2. The number of cubic centimetres of separated emulsified layer.
3. The number of cubic centimetres of separated clear or turbid oil above the emulsified layer; and
4. The percentage of water or moisture in the separated oil above the emulsified layer.

There should at most be only a line of emulsion between the water and the oil.

The number of cubic centimetres of clear or turbid oil above the emulsified layer, less the percentage of water or moisture contained in the oil, is the (Conradson) percentage of demulsibility of the oil.

NOTES ON EMULSIFICATION.—When oils are acid-treated for the purpose of removing undesirable hydrocarbons, the acid is then washed out and neutralized. This acid treatment is the source of certain "sulpho compounds" which may be present in the oils if not properly refined. When an emulsion test is made, a fine line of separation between the oil and the clear water indicates the absence of these acid compounds, while a curdled mass floating on the milky water below indicates a quantity of "sulpho compounds" present. Samples of oil to be submitted to this test should not have been allowed to stand in the sunlight for a long time, as the ultraviolet rays in sunlight tend to cause oils to have less resistance to emulsification.

If lubricating oil contains "sulpho compounds" it has its rate and percentage of emulsification increased. In the case of oils to be used for the lubrication of combustion engines, if the oil readily absorbs oxygen and polymerizes, or undergoes chemical change when heated while in service in the engine crank-case, it will produce a voluminous emulsion under test.

COLLOIDAL CHARACTERS OF FATTY ACIDS.—(Paper by Messrs. Wells and Southcombe, *Journal Society of Chemical Industry*, 1920, pp. 51–60T, on "The Theory and Practice of Lubrication—the Germ Process"):

"During recent years a great deal of attention has been devoted to the study of the colloidal characters of the fatty acids, and it has been

shown that while the lower members of the fatty acid group possess relatively little colloidal character, the higher members are highly colloidal in character. Donnan and Potts have shown that there is a gradation in these properties as one ascends the scale, lauric acid occupying a sort of intermediate position. Also the lower members of the series possess strong acid characteristics, while the higher members are very weakly acid. Now the fatty acids which occur in commercial oils (fatty) are never pure chemical individuals, but are mixtures in varying proportions of a considerable number of fatty acids. Cocoanut oil, for example, is characterized by containing appreciable percentages of the lower members of the series, while rape oil rarely contains anything but the higher members.

"It is only to be expected, therefore, that the behavior of these oils will differ in accordance with the fatty acid groups which predominate in them, and it is possible to reproduce the capillary properties of any particular animal or vegetable oil by adding suitably chosen fatty acids to mineral oil.

"Consider the case of a steam engine using saturated steam, where there is a tendency for condensation of water to occur in the cylinder and valves. It follows in such a case that the presence of a substance in the oil which lowers the surface tension against water will, in such circumstances, assist in the formation of oil films by enabling the oil to spread more readily or by overcoming the tendency of the water to wash the oil film off.

"Now the phenomenon of emulsification is dependent upon the colloidal properties of the oil, while demulsification is brought about by a greater concentration of hydrogen ions. Consequently one would expect the oil containing the higher members of the fatty acid group to possess an emulsifying tendency, while one containing the lower members will possess a deëmulsifying tendency. This is a feature which we have tested by shaking oils and water at various temperatures for long periods of time, and to a great extent we have been able to substantiate this view as the result of experiments."

* GREASE TESTS

EXAMINATION OF LUBRICATING GREASES.—The following tests cover the general requirements: (*a*) Free acid; (*b*) Dropping point; (*c*) Flash; (*d*) Soap content; (*e*) Free oil or fat; (*f*) Free lime; (*g*) Water content; (*h*) Fillers; (*i*) Percentage of ash; (*j*) Loss of weight after heating; (*k*) Friction test.

The consistency of greases is usually determined in the laboratory by the use of the consistometer. (See index.) There is a great need for a satisfactory grease viscosimeter.

It is difficult to determine the quality of a grease by the appearance. Cheap oils, such as gas oils, may be used, and the grease thickened up, which will produce a grease with little real lubricating value, since the lubrication depends upon the oil content.

The addition of fatty oils to heavy hydrocarbon oils increases their adherence to metallic surfaces and decreases the tendency of the hydrocarbon oil to withdraw from points where there is high local heating.

The surface of greases in their containers may undergo slight discoloration from exposure to the air. This discoloration is due to a slight oxidation, which penetrates the grease for a small distance below the surface, but which does not affect its lubricating qualities.

Greases are often dyed to give them a distinct color.

Grease may be tested by the following simple tests:

(*a*) The presence of free acid may be detected by melting the grease and testing with litmus paper (blue litmus).

(*b*) The evaporation or volatility test may be made by heating a measured quantity of the grease to a temperature of 200° Fahr. for two hours and then weighing the sample to ascertain the loss in weight.

(*c*) A general idea of the extent of the filling, if any, may be had by heating a small quantity of the grease just to the melting-point, and keeping it in a liquid state and perfectly still for an hour. A badly filled grease will leave a residue, its size depending upon the amount of the filling. To obtain any sort of accuracy, this test must be made by a chemist, but an approximate idea of the filling may be had from a field test.

(*d*) To determine whether the grease is alkaline in reaction, melt it to a liquid state, thoroughly stir, and apply a piece of red litmus paper.

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* See index for test methods of Committee on Standardization of Petroleum Specifications.

CONSISTOMETER

CONSISTOMETER, THE ABRAHAM.—This machine is intended to determine the hardness or consistency of bituminous materials, but can also be used for the comparison of greases and plastic lubricants.

Fig. 34, Sec. 6, shows a general view of the instrument. The consistometer can be used for testing at any desired temperature, although 32°, 77° and 115° Fahr. are the ordinarily adopted standards. The range of the instrument is sufficiently great to include all commercial bituminous substances from semi-liquids to hard, brittle substances.

Three plungers are provided of special form, having reduced shanks and round, flat heads of the following dimensions:

	No. 1	No. 10	No. 100
Diameter of head	1.13 mm.	3.56 mm.	11.28 mm.
Area of head	1 sq. mm.	10 sq. mm.	100 sq. mm.
Volume displaced in penetrating 1 cm.	0.01 c.c.	0.10 c.c.	1.00 c.c.
Relation between plungers	1	10	100

The method of testing consists in forcing one of the plungers into the substances at a uniform rate of speed of 1 c.c. per minute. The force required is automatically registered in grams.

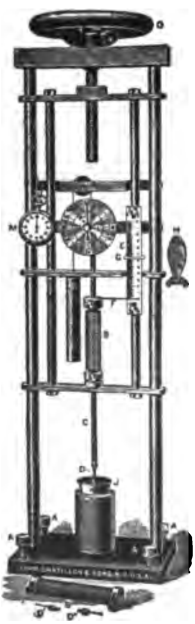


Fig. 34. Sec. 6.—The Abraham consistometer.

For any substance the number of grams required to effect this displacement directly proportional to the volume displaced. The volumes displaced by the plungers per minute are 0.01 c.c., 0.10 c.c., and 1.00 c.c., respectively. Hence the relation 1:10:100. This only holds true for the special form of plungers supplied with the instrument, in which the frictional adhesion of the substance to the sides is entirely eliminated.

All readings are expressed in terms of plunger No. 100; *i.e.*, the readings obtained with plunger No. 10 are multiplied by 10, and those obtained with plunger No. 1 by 100.

The Hardness or Consistency of the substance is equal to the cube root of this number of grams.

Two interchangeable springs are used with the instrument: One for reading in grams, on a scale ranging from 0 to 1000 grams in 10-gram divisions, the other for reading in kilograms, on a scale ranging from 0 to 10 kilograms, in 0.1-kilogram divisions. When using plungers No. 1 and No. 10, the kilogram spring only should be employed. In using plunger No. 100, either the gram or the kilogram spring may be employed, depending upon the hardness of the material.

The following table is used to convert the consistometer readings to points hardness. In every instance the hardness is designated as the cube root of the number of grams which must be applied to the

plunger No. 100 (area 100 sq. mm.) to cause it to displace the substance at the speed of 1 centimetre per minute.

The instrument is manufactured by Messrs. John Chatillon & Sons, New York.

When operating the instrument, the pressure is applied to the plunger by turning the hand-wheel *O*, and the speed of displacement controlled by following the pointer *K*, on the dial *L*, which should be caused to revolve at the same rate of speed as the second hand of the chronometer *M*. The numbers on the dial *L* correspond with those of the second hand on the chronometer. At the termination of 60 seconds, after the pointer on the dial has made one revolution, the pressure is relieved on the plunger and the maximum reading on the indicator *G* on the scale *E* is then noted, and the corresponding degree of hardness ascertained by referring to the table on the next page.

EXAMINATION OF PETROLEUM OILS AND PRODUCTS

When examining samples of petroleum products with a view to determining the proper grade or product to offer in competition with the sample, the following properties of the sample should be determined:

Cylinder oil	*Black oils*	*Engine or spindle oil*
Gravity	Gravity	Gravity.
Flash (open)	Flash (open)	Flash (open).
Flash (closed)	Pour (cold test)	Flash (closed).
Pour	Per cent. fatty oil	Viscosity at 100° Fahr.
Viscosity at 212° Fahr.	Gasoline test	Cold test (cloud).
Per cent. fatty oil	Viscosity at 130° Fahr.	Cold test (pour).
Color		Per cent. fatty oil.
Gasoline test	*Absorbent oil*	Color.
	Gravity	
Paraffin wax	Flash test (open)	*Gasoline or naphtha*
Per cent. oil in wax	Cold test (cloud)	Gravity.
Color	De-emulsibility figure	Color.
Odor, if any		Overpoint.
Melting-point	*Wool oil or cutting oil*	Per cent. at 158° Fahr.
	Gravity	Per cent. at 212° Fahr.
Petrolatum	Cold test (cloud)	Per cent. at 302° Fahr.
Consistency	Color	Per cent. at 320° Fahr.
Melting-point	Per cent. fatty oil	Dry-point.
Color	Viscosity at 100° Fahr.	Flash.

THE ABRAHAM CONSISTOMETER

TABLE FOR CONVERTING CONSISTOMETER READINGS INTO POINTS HARDNESS

Plunger No. 100 (100 sq. mm.) Gram Spring

Gms. Appl'd	0	10	20	30	40	50	60	70	80	90
0	0.00	2.15	2.71	3.11	3.42	3.68	3.91	4.12	4.31	4.48
100	4.64	4.79	4.93	5.07	5.19	5.31	5.43	5.54	5.65	5.75
200	5.85	5.94	6.04	6.13	6.21	6.30	6.38	6.46	6.54	6.62
300	6.69	6.77	6.84	6.91	6.98	7.05	7.11	7.18	7.24	7.31
400	7.37	7.43	7.49	7.55	7.61	7.66	7.72	7.775	7.83	7.88
500	7.94	7.99	8.04	8.09	8.14	8.19	8.24	8.29	8.34	8.39
600	8.43	8.48	8.53	8.57	8.62	8.66	8.71	8.75	8.79	8.84
700	8.88	8.92	8.96	9.00	9.045	9.09	9.13	9.17	9.21	9.24
800	9.28	9.32	9.36	9.40	9.44	9.47	9.51	9.55	9.58	9.62
900	9.65	9.69	9.73	9.76	9.80	9.83	9.86	9.90	9.93	9.97

Plunger No. 100 (100 sq. mm.) Kilo Spring

Kil. Appl'd	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1.0	10.0	10.3	10.6	10.9	11.2	11.4	11.7	11.9	12.2	12.4
2.0	12.6	12.8	13.0	13.2	13.4	13.6	13.75	13.9	14.1	14.3
3.0	14.4	14.6	14.7	14.9	15.0	15.2	15.3	15.5	15.6	15.7
4.0	15.9	16.0	16.1	16.3	16.4	16.5	16.6	16.75	16.9	17.0
5.0	17.1	17.2	17.3	17.4	17.5	17.65	17.8	17.9	18.0	18.1
6.0	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.85	18.95	19.0
7.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.75	19.8	19.9
8.0	20.0	20.1	20.2	20.25	20.3	20.4	20.5	20.6	20.65	20.7
9.0	20.8	20.9	20.95	21.0	21.1	21.2	21.25	21.3	21.4	21.5

Plunger No. 10 (10 sq. mm.) Kilo Spring

Kil. Appl'd	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1.0	21.5	22.2	22.9	23.5	24.1	24.7	25.2	25.7	26.2	26.7
2.0	27.1	27.6	28.0	28.4	28.8	29.2	29.6	30.0	30.4	30.7
3.0	31.1	31.4	31.7	32.1	32.4	32.7	33.0	33.3	33.6	33.9
4.0	34.2	34.5	34.8	35.0	35.3	35.6	35.8	36.1	36.3	36.6
5.0	36.8	37.1	37.3	37.6	37.8	38.0	38.3	38.5	38.7	38.9
6.0	39.1	39.4	39.6	39.8	40.0	40.2	40.4	40.6	40.8	41.0
7.0	41.2	41.4	41.6	41.8	42.0	42.2	42.4	42.5	42.7	42.9
8.0	43.1	43.3	43.4	43.6	43.8	44.0	44.1	44.3	44.5	44.6
9.0	44.8	45.0	45.1	45.3	45.5	45.6	45.8	45.9	46.1	46.3

Plunger No. 1 (1 sq. mm.) Kilo Spring

Kil. Appl'd	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1.0	46.4	47.9	49.3	50.7	51.9	53.1	54.3	55.4	56.5	57.5
2.0	58.5	59.4	60.4	61.3	62.1	63.0	63.8	64.6	65.4	66.2
3.0	66.9	67.7	68.4	69.1	69.8	70.5	71.1	71.8	72.4	73.1
4.0	73.7	74.3	74.9	75.5	76.1	76.6	77.2	77.75	78.3	78.8
5.0	79.4	79.9	80.4	80.9	81.4	81.9	82.4	82.9	83.4	83.9
6.0	84.3	84.8	85.3	85.7	86.2	86.6	87.1	87.5	87.9	88.4
7.0	88.8	89.2	89.6	90.0	90.45	90.9	91.3	91.7	92.1	92.4
8.0	92.8	93.2	93.6	94.0	94.4	94.7	95.1	95.5	95.8	96.2
9.0	96.5	96.9	97.3	97.6	98.0	98.3	98.6	99.0	99.3	99.7
10.0	100.0	100.3	100.7	101.0	101.3	101.6	102.0	102.3	102.6	102.9

Courtesy, John Chatillon & Sons, Makers, New York.

FRICTION-TESTING MACHINES

The only true method of learning the value of a lubricant as a friction reducer and its applicability to fulfil a given mechanical requirement is to submit it to practical tests. In the past tests have been largely carried out in the laboratory by means of a friction-testing machine.

L. Ubbelohde says in one of his articles on the "Theory of Lubrication": "The mechanical testing of lubricants is accomplished by determining the coefficients of friction for the oil under observation, by applying it to the journal of the testing machine under varying conditions of velocity, pressure, etc." His investigations have shown that the coefficients of friction as determined on these machines are dependent upon the viscosities of the oils alone. If, therefore, a number of oils of different viscosities are systematically tested, and the coefficient of friction corresponding to each viscosity is determined for that particular machine, these coefficients of friction will apply without further testing to all oils of the same viscosities, for any particular running temperature.

"The reason that experimenters have not previously recognized this fact is due to the condition that viscosity has not been expressed in a system of units that is proportional to the viscosity (specific viscosity), but in arbitrary units, which cannot be applied to computation as being proportional to viscosity. Also the relationship existing between temperature and viscosity has not definitely been determined."

Oils which give satisfactory results on the friction-testing machine may act very differently under practical working conditions.

The only similarity between the conditions of actual working requirements and those produced in the testing machine is that of pressure and speed, and in actual use even these conditions are far from being uniform. An oil which works well on the smooth journal of the testing machine may give very poor results under the ordinary conditions of wear. For instance, in case the oil is of such a nature that the heat generated by an abrasion on a working bearing or journal prevents the oil from reëstablishing the lubricating film readily, the effect is apt to be a "hot box."

Again the qualities necessary in an oil to permit its feeding properly to all parts to be lubricated are in no way tested by the friction-testing machine. Instead of its performance under perfect conditions, it is rather the ability of the oil to meet the abnormal conditions of actual use that determines its value as a lubricant.

The differences in frictional resistance, as shown by the tests of various oils on the friction tester, are due to the viscosities of the oils, and while, for light-bodied oils, such as spindle oils, cotton-mill oils and similar oils, the frictional resistance produced by the viscosities of the oils is of importance, it is of little importance or significance in the case of heavy machinery.

However, for purposes of scientific comparative investigation of the theoretical performance of various lubricants, the friction-testing machine is of value. (See index for curves showing effects of varying, bearing pressures, feed, speed, viscosity, etc.)

THURSTON RAILROAD LUBRICANT TESTER.—A line drawing of a widely used friction-testing machine, known as the Thurston Railroad Lubricant Tester, is shown in Fig. 35, Sec. 6.

This machine essentially consists of a shaft revolving between the bearings B, B^1, B^2. The pressure on B can be regulated by adjusting the coiled spring C. The amount of pressure produced by the coiled spring on the bearing B is indicated by the index pointer D.

A thermometer T registers the amount of frictional heat generated by the bearing B. The machine is driven by the cone pulley E.

The oil to be tested is introduced into the bearing B in measured quantities. This bearing has the same dimensions as the usual car journal. The pressure on the bearing is brought to the desired intensity by tightening the spring C by means of the nut X.

The friction developed between the rotating journal and the bearing causes a displacement of the pendulum K. The journal is turned at a

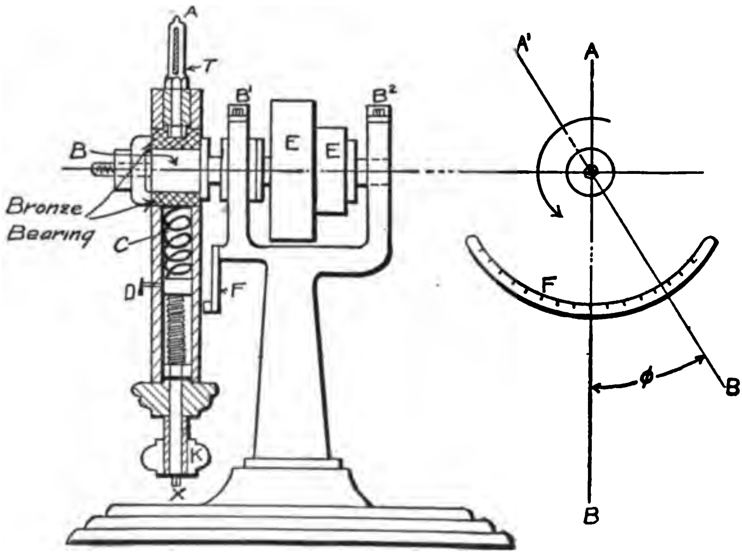


Fig. 35. Sec. 6.—Outline drawing of Thurston railroad lubricant tester.

constant speed. The arc scale F is so graduated that by dividing the reading of the deflection angle ϕ on the scale F by the pressure shown by the index D, the coefficient of friction is obtained.

This coefficient of friction can then be compared with the results of tests on other oils obtained under the same running conditions on the same machine.

There are several other more highly improved friction-testing machines in use.

NAVAL FRICTION TESTER.—Fig. 36, Sec. 6, and Fig. 37, Sec. 6, show two views of the friction-testing machine designed and used at the United States Naval Experiment Station at Annapolis, Md.

The springs are calibrated. The journal driving motor is of the variable speed type, so that any desired bearing speed may be obtained.

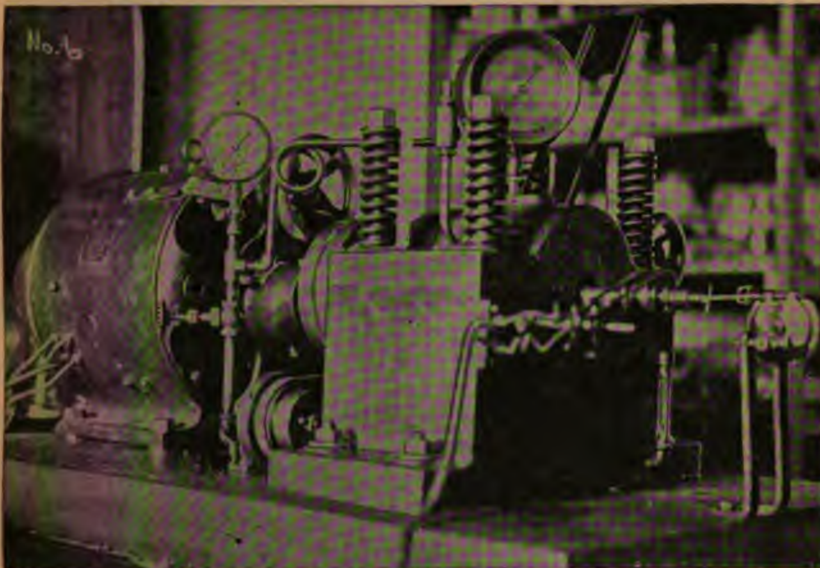


FIG. 36. SEC. 6.—Friction testing machine at the United States Naval Experimental Station at Annapolis, Md.

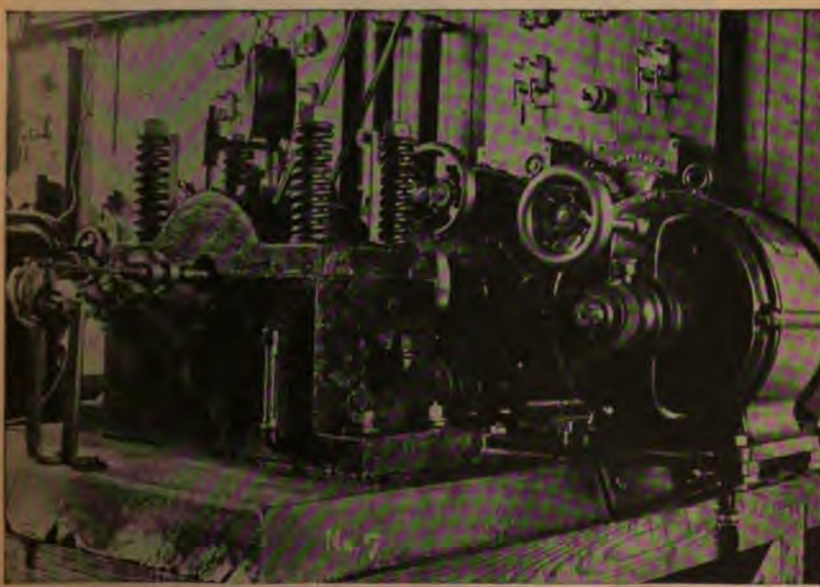


FIG. 37. SEC. 6.—Another view of the United States Experimental Station friction testing machine.

A pressure gauge indicates the oil pressure, as supplied by a rotary pump, motor driven, as shown.

The bearing is equipped with an electric heating coil, the electric current being supplied through the "fingers" and rings carried by the small projecting shaft, shown at the side of the bearing.

It may be added that the constant temperature maintained in the bearing of the above-described tester does not permit of a fair comparison

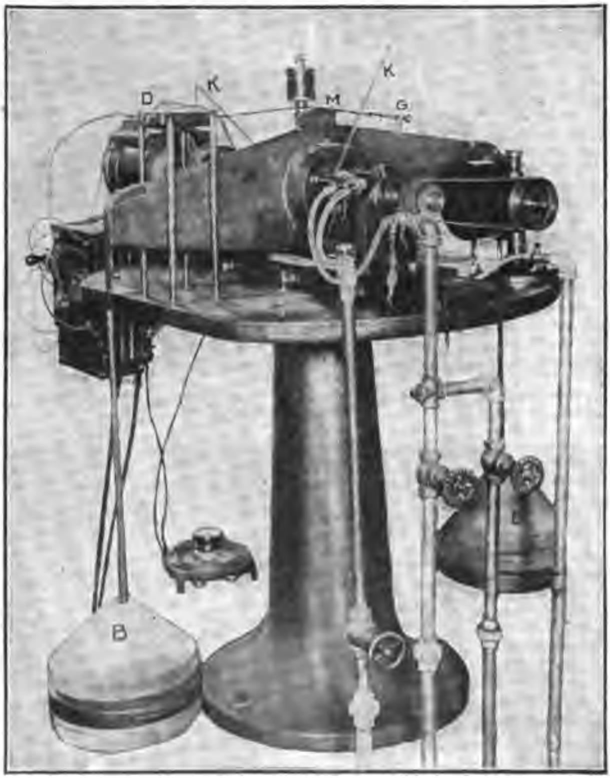


FIG. 38. SEC. 6.—Golden oil testing machine. (Courtesy Engineering Experiment Station. University of Missouri.)

of lubricating oils of different viscosities and made *from different crudes.* If the bearing is maintained at a temperature of 135° Fahr., it gives a distinct advantage to those oils made from asphalt base crudes and imposes a handicap upon those oils made from paraffin base crudes. In one case the result is to reduce the high viscosities of the asphalt base crudes to lower and more efficient working viscosities, which required a high bearing temperature; while in the case of the paraffin base oils, having lower

viscosities at 100° Fahr. than the asphalt oils, it is not practical to compare their coefficients of friction at a temperature much higher than these oils would normally run, since there is no necessity for high bearing heats to reduce their viscosities to the required working values. Results obtained in this manner for comparative purposes mean absolutely nothing and may be likened to a law which is only half stated.

The pressure in the oil film is indicated by the gauge on top of the bearing cap, as shown.

The oil is drained back into the reservoir below the bearing, and after settling is again pumped to the bearing.

GOLDEN OIL-TESTING MACHINE.—The following description of this machine is given in the University of Missouri Bulletin, Engineering Experiment Station, Vol. 4, No. 4, by A. L. Westcott (See Fig. 38, Sec. 6, and Fig. 39, Sec. 6):

"The bearing consists of a babbitted sleeve, which is fitted to a shaft *H*. This shaft runs in roller bearings *F* and is driven by a motor, through the couping *L*. * * * A cast-iron beam, *A*, is bored out at the centre of its length to fit the bearing, to which it is fastened by screws. The ends of this beam are circular arcs, struck from the shaft centre. Flexible bands, *C*, are attached to *A* and support weights, *B*, by means of which the load on the bearing is applied. The casting which forms the bearing is cored out, so as to provide a space or jacket in which cold or hot water or steam may be circulated in order to control the temperature. At *D* a spring balance is supported upon four vertical rods, that are screwed into the machine top. This balance is connected, by means of a thin strip of spring steel, to the post, with screw adjustment at *G*. The steel strip leads over a part, *M*, cast on the upper side of *A*, and machined to form a circular arc, whose centre is the centre of the shaft. The radius of this arc is 6 inches, and the height of the balance is such that it exerts a pull, always in a horizontal direction. The weight on the end of the beam opposite to *D* must be made a little greater than that on the adjacent end, so that a positive pull will always be exerted whichever direction the motor is running. A pointer, *E*, attached to one end of the table top, enables the operator to bring the beam to any desired angular position. Holes are drilled in each end of the bearing for the insertion of the thermometer, *K*, the bulbs of which are brought close to the side of the journals, so as to get as nearly as possible a correct indication of the bearing temperature."

The formula for coefficient of friction is deduced as follows:

W = The total load on the bearing, pounds.
P = The pull on the spring balance when running in a clockwise direction, pounds.
P_2 = The pull on the balance when running anti-clockwise.
D = Diameter of journal, inches.
ϕ = Coefficient of friction.

$$\phi W \frac{D}{2} = 6 \frac{P_1 - P_2}{2}$$

$$\phi = (P_1 - P_2) \frac{6}{WD}$$

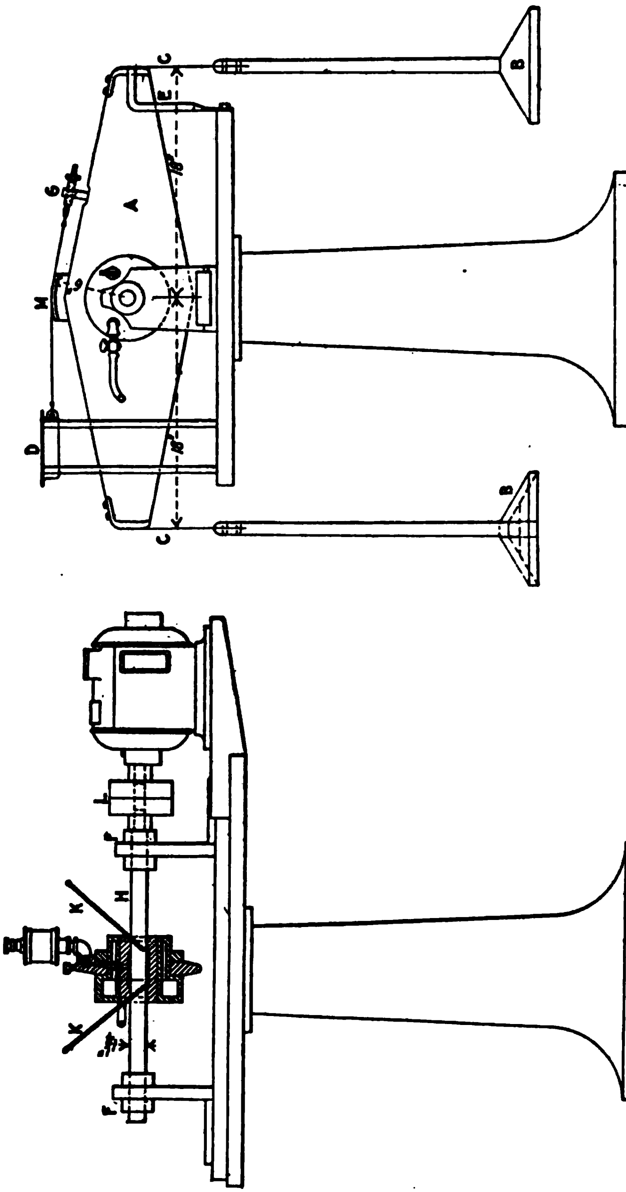


FIG. 39. SEC. 6.—Side and end views of Golden oil testing machine. (Courtesy Engineering Experiment Station, University of Missouri.)

For any load, W, the constant $\frac{6}{WD}$ may be computed once for all, and the formula takes this form:

$$\phi = C\,(P_1 - P_2)$$

Mr. Westcott further states: "As originally constructed, the machine differed in several details from that shown in Fig. 38, Sec. 6. Instead of the post and screw adjustment at G, the balance was connected by a

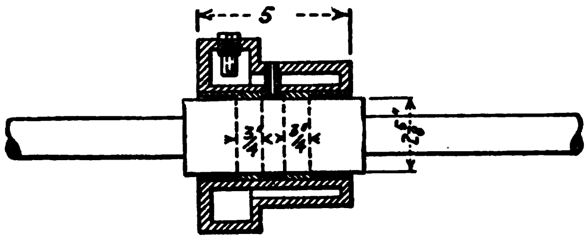


FIG. 40. SEC. 6.—Bearing of testing machine shown in Fig. 39, Sec. 6.

light chain to a pin at M, the idea being to take up or let out the chain link by link as required. Also the weights B were suspended by chains at C. It was found that these chains were a very unsatisfactory arrangement. It was necessary, in order to get reliable data, to keep the beam always

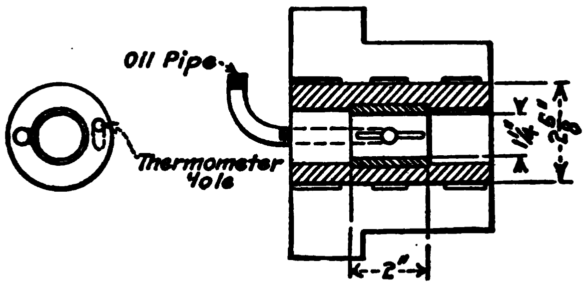


FIG. 41. SEC. 6.—Bearing of testing machine shown in Fig. 39, Sec. 6.

in exactly the same angular position. A very slight change in the position of the beam would make a considerable difference in the pull on the balance. A chain consisting of a series of rigid links is not sufficiently flexible for the purpose. Changes in the angular position of the beam produced slight changes in the radii of the centre lines, through the weights B, and this, of course, meant an upsetting of the condition of equilibrium between the pull of the balance and the frictional turning movement. It was necessary, therefore, to adjust the beam position

with great care, so as to be exactly the same when running in each direction. The pointer, *E*, was added for this purpose. Later the chain hangers were replaced by thin steel bands at *C*. This change produced a marked improvement in the operation of the machine. It was still found to be desirable to keep the beam in one position, and to accomplish this better, the screw adjustment at *G* was added. The bearing supplied by the makers was 2 5/8 inches in diameter and 5 inches long. The largest

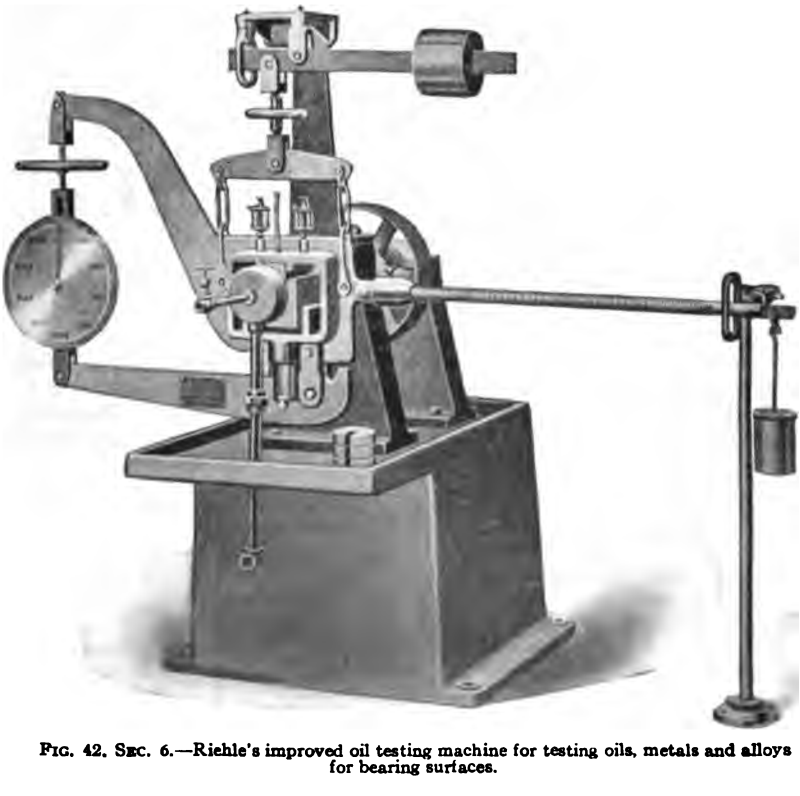


Fig. 42. Sec. 6.—Riehle's improved oil testing machine for testing oils, metals and alloys for bearing surfaces.

load that the suspending chains would safely carry was only about 50 pounds per square inch of projected area. * * In order to carry larger bearing pressures, the length of the bearing was reduced to 1 1/2 inches, as shown in Fig. 40, Sec. 6, these being two rings of 3/4 inch length each. * * * The bearing as shown in Fig. 40, Sec. 6, was not satisfactory, as it appeared that the proportion of length to diameter was bad, at least for grease lubrication * * * The bearing was changed, as shown in Fig. 41, Sec. 6. The diameter was reduced to 1 1/4 inches and the length increased to 2 inches. The form of bearing, therefore, proved to be a great improvement."

RIEHLE OIL-TESTING MACHINE.—The following description is by the makers:

This machine can be used for determining the coefficient of friction, etc., of lubricating oils, or for determining the wearing qualities of lubricating oils and bearing metals. (See Fig. 42, Sec. 6.)

The machine consists of a pulley carried between two bearings and driving an overhanging test journal; on this overhanging part is the test-bearing frame which is free to turn about on the test journal. This frame is supported on the test journal by the test bearings or "brasses," the lower one of which is adjustable in a vertical direction only. From the arm of the frame is hung a hand wheel and a spring balance which, acting through the lower lever, is used to exert any given pressure on the test journal, the total pressure so exerted being read on the dial of the spring balance, which reads by 25 pounds. This pressure is carried by the test journal alone, and, therefore does not cause friction and consequent heating at the other bearings of the machine. From the construction of this machine it is easily seen that the total pressure on the test journal is made up of two equal pressures, since the weight of the parts which would otherwise add pressure to the upper bearing is counterbalanced by the upper lever mechanism. The force of friction is measured by moving out the sliding poise on the friction beam, which reads by 1 pound.

The temperature of the test journal is noted from a thermometer inserted in the upper bearing. The test journal is hollow, so that when desirable water can be passed into it to take up the heat and maintain an even temperature; also the driving shaft rotates on annular ball bearings so that these bearings generate no heat to cause error in the temperature readings of the test journal. The test journal can be removed without taking out the driving shaft and pulley.

The base of this machine is very heavy, so as to absorb all vibration. A large shelf projects underneath the test bearings to catch any oil drippings, while the oil bath is so made as to prevent the "throwing" of oil due to the rapid rotation of journal.

The bearings may be oiled by oil cups or by an oil bath, the latter method being preferable.

A pulley and a stand are provided for attaching a tachometer if desired. Unless specially ordered, the tachometer itself is not furnished.

To remove the test bearings: Lower the lower bearing by means of the large hand wheel and raise the frame by means of the small hand wheel until the upper bearing can be taken out; then lower the frame until the lower bearing can be taken out.

Pulleys on machine, 15 inches (38.1 cm.) diameter by 4 inches (10.16 cm.) face.

Diameter of journal, 3 inches (7.62 cm.)

Length of journal, 5 1/8 inches (13.02 cm.).

Size of bearings, 5 inches (12.7 cm.) by 2 inches (5.08 cm.).

Total projected area of bearings, 20 square inches (129 sq. cm.).

Speed from 100 R. P. M. to 1000 R. P. M. to suit purchaser.

Power required to run this machine varies from 5 H. P. to 12 H. P., depending on conditions.

SECTION 7

LUBRICATION AND FRICTION

FRICTION LOSS IN THE UNITED STATES

TOTAL HORSE-POWER IN THE UNITED STATES.—According to the last census, the total primary horse-power produced in the United States was 18,675,376. It is safe to estimate that fully 50 per cent. of this power was wasted in overcoming unnecessary friction. If the average cost of producing a horse-power is assumed to be $20, the enormous cost of friction can thus be easily estimated.

FRICTION

DESCRIPTION AND EFFECT.—There is a tax which all operators of machinery must pay whenever their machines are in motion, which may be called the Friction Tax.

FRICTION.—Friction can best be described as that force which resists the relative motion of one particle or body in contact with another particle or body and resists their sliding one on the other at the surfaces of contact.

THREE KINDS OF FRICTION.—There are three kinds of friction:

(*a*) Rolling friction between solids.
(*b*) Sliding friction between solids.
(*c*) Fluid friction between the particles of a fluid.

SLIDING FRICTION

KINETIC FRICTION.—The frictional resistance between two bodies in contact when *moving relatively* to each other is called Kinetic Friction or Friction of Motion.

LAWS OF SLIDING FRICTION.—The following laws govern the conditions of friction between dry and unlubricated surfaces:

(*a*) For small loads at low speeds, the friction between dry surfaces is proportional to the pressure between the surfaces.

(*b*) The friction between dry surfaces is not affected by the area of the surfaces, providing the pressure is constant. All sliding surfaces, no matter how carefully they may be finished, are known to consist of minute projections and depressions (see Fig. 1, Sec. 7). When two surfaces are held in contact by any force, these projections and hollows on the contact faces interlock and resist sliding or relative motion.

According to Dr. Hele Shaw in a lecture recently delivered on " Clutches " before the Royal Institute, with reference to friction between two surfaces in contact and the principle that two such surfaces in contact and in relative motion develop friction, due to the fact that the pro-

tuberances of one surface engage in depressions of the other surface, the belief is now set forth that, when two such surfaces are in contact, a certain number of particles on the surfaces actually touch each other, and the friction effect is due to the attractive force existing between these particles. Doctor Shaw states that, of course, if very rough surfaces are rubbed over one another, bits are knocked off and more work is done; but, he states, this is not true friction, which he describes as being due to the mutual attraction of particles of matter. A parallel comparison is set forth in that it can be shown directly if true surfaces are placed in contact, when a resulting attraction will occur as, for instance, 11 copper cubes, the whole weighing 98 grams, could be made to hang one from another in a vertical string. This phenomenon is not due, he states, to any "sucker effect," but is explained purely by molecular attraction. In this connection La Place calculated that this effect could not be detected over a greater distance than 5×10^{-7} c.c., which is about 1/2,000,000 inch.

FRICTION OF REST OR STATIC FRICTION.—Friction of Rest or Static Friction must be distinctly separated from Kinetic or Friction

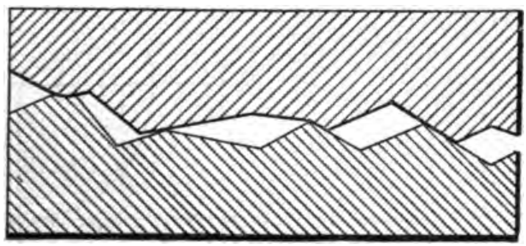


FIG. 1. SEC. 7.—Magnified surfaces of contact.

of Motion. It requires a greater force to start one surface sliding over another than to maintain the sliding after the motion has begun. Therefore, Static Friction exceeds Kinetic Friction.

COEFFICIENT OF FRICTION IS VARIABLE.—The value of the Coefficient of Friction for lubricated surfaces varies with the velocity, pressure and temperature of the contact surfaces. If the two contact surfaces as shown in Fig. 1 are pressed together with an increased force or pressure, the various projections and depressions are more closely interlocked, and, therefore, offer greater resistance to relative motion. This demonstrates that the friction is increased directly as the pressure. The Coefficient of Friction for any contact surfaces is the ratio of the maximum resistance of friction to the normal or perpendicular pressure holding the surfaces together.

That is: F_c equals $\frac{R}{P}$ where $\begin{cases} R = \text{Maximum resistance to motion due to friction.} \\ P = \text{Normal force holding the surfaces together.} \\ F_c = \text{Coefficient of friction.} \end{cases}$

ROLLING FRICTION.—The resistance offered to the rolling of a spherical or cylindrical body across a plain or curved surface is called Rolling Friction.

Referring to Fig. 2, Sec. 7, it is the force required to lift the rolling object over the projection *N*. Rolling friction is similar to the conditions prevailing when a pinion rolls along a rack and the pinion teeth are lifted out.

Referring to Fig. 2, Sec. 7, the force *P* acts to roll the body *Y* through the bent lever *ab*. At the other end of the lever *ab* the weight of the body, or *W*, acts perpendicularly to the contact surface.

In practical conditions, the lever *B* is proportionally much shorter than the lever *a* than is shown in the illustrative figure. Therefore, the resisting weight of the wheel, acting through the lever *B*, is much less than the

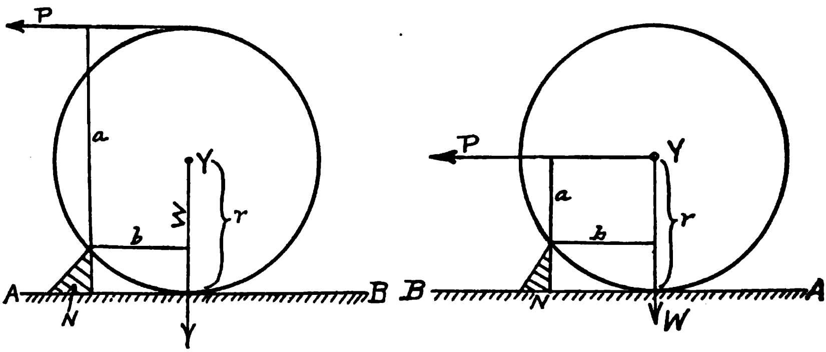


Fig. 2. Fig. 3.

Figs. 2 and 3. Sec. 7.—Rolling friction.

force *P* acting through the lever *a*. Therefore, the force *P* which is required to roll the object *Y* is usually much less than would be necessary to slide this object along the contact surface.

The force *P* may be applied at the centre, as is shown in Fig. 3, Sec. 7, or it may be applied at the circumference, as is shown in Fig. 2, Sec. 7. When the contact surface *AB* (Fig. 3, Sec. 7), is very smooth, thus making the projections *N* minute, the lengths of the radius *r* and lever *ab* practically coincide.

The friction between the rail and the wheel of a railroad car, which causes the car wheel to turn, notwithstanding the retarding pressure of the brake shoe, is a resistance to the "sliding" of the wheel on the rail surface, and is, therefore, not rolling, but sliding, friction.

LAWS OF ROLLING FRICTION.—The laws of rolling friction would appear to be identical with those of sliding friction, with the proviso that resistance varies with radius of the rolling body. The law may be expressed as follows:

$$R = \frac{F W}{r}$$

Where R = Frictional resistance.
F = Coefficient of friction.
r = Radius of rolling body.

CAUSE OF ROLLING FRICTION.—The irregularities of the contact surfaces of even supposedly perfectly smooth plane and cylindrical bodies force the rolling body to lift itself over the minute projections which resist the rolling action. This resistance is the cause of Rolling Friction.

The rate of slipping between the contact surfaces of a rolling contact bearing (for a spherical body, such as a ball in a ball bearing, is slightly flattened under load), is probably so low that the coefficient of friction very slowly decreases as the bearing speed increases.

FLUID FRICTION

FLUID FRICTION.—Fluid friction is of great importance in the study of lubrication. When the particles of a fluid are in motion and the outer surfaces of the fluid are in contact with solid surfaces, the fluid body is divided into numerous layers within itself. The friction produced by the slipping of these layers composing the fluid over one another and by the "rubbing effect" between the fluid particles is called Fluid Friction.

NOTES ON FLUID FRICTION.—The friction of liquids moving in contact with solid bodies is independent of the pressure.

This is due to the fact that the "lifting" of the particles of the fluid over the projections on the solid surface (as is described in connection with rolling friction) is aided by the pressure of the surrounding fluid particles, which strive to occupy the places made vacant by the particles of the fluid that have passed over the solid projections.

Therefore, for fluids there is no coefficient of friction corresponding to that of solids, namely: $\frac{\text{resistance}}{\text{pressure.}}$

The frictional resistance is considered to be directly proportional to the area of the contact surfaces.

Certain investigators have stated that fluid frictional resistance could be determined by the following formula:

$$\text{Fluid friction} = C \times A \times V^{(n)}$$

Where C = A coefficient depending upon the velocity and the character of the surfaces.
A = Area of the contact surface.
V = Velocity.
(n) = One (1) at low speeds, but at a certain critical velocity (n) changes to two (2), owing to the breaking up of the fluid stream into eddies and counter-currents.

OILINESS, NOTES ON.—In discussing a paper by R. Mountford Deeley on "Oiliness and Lubrication," read before the Physical Society of London, Mr. L. Archbutt pointed out that the following conditions should be clearly distinguished in considering lubricating problems. (1) Cases where two solid surfaces were completely separated by a film of oil, as with properly fitted journals revolving at high speed and abundantly fed with oil, and (2), Cases where, owing to the shape and condition of the surfaces, low speed, high pressure or inadequate oil supply, the oil film could not form completely and became broken, so that the solid surface came into contact. In the first instance, the friction was due to the viscosity of the oil and the theory of Reynolds and the chemical characteristics of an oil could be used as guides. In the second case, the circumstances were different. * * * Oils alike in viscosity might have different friction-reducing values, and it is here that the property termed "oiliness" becomes important. These remarks of Mr. Archbutt are of especial interest at this time. Mr. Deeley's view is that oiliness enables an oil, or some constituent of it, to combine with the bearing surfaces and form a lubricating film, and is in accord with Langmuir's view. (See index.)

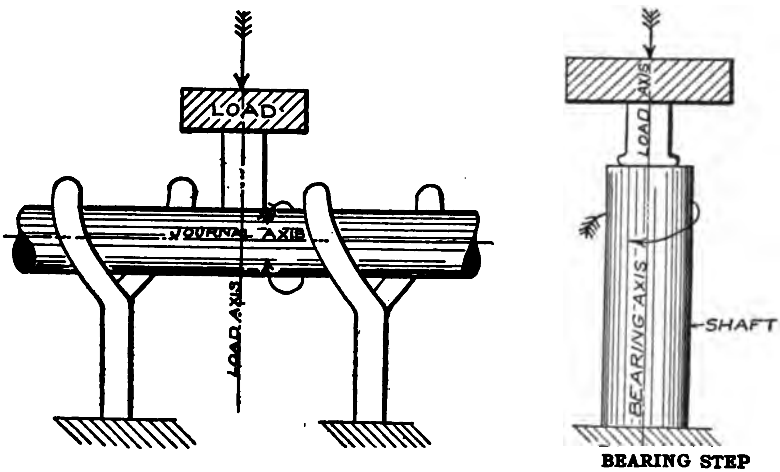
SECTION 7a

BEARINGS AND THEIR LUBRICATION

BEARINGS

DEFINITION OF BEARINGS.—Bearings are surfaces or points of contact between the frame of a machine and the moving parts. They support and guide the rotating, sliding or revolving parts, which are called journals, pins, spindles and shafts.

All bearings may be classed in two main divisions, depending upon the way they carry the load. If the load is carried at right angles to the axis of the bearing, the bearing is called a "journal bearing" (see Fig. 1, Sec. 7a). If the load acts in a line parallel to the axis of the bearing, the bearing is called a "thrust bearing," or a "step bearing."



JOURNAL BEARING STEP BEARING

FIG. 1. SEC. 7a.—Journal and step bearings.

Journal and step bearings may have either sliding or rolling contact with the moving parts. Rolling contact bearings are equipped with either ball or roller bearings.

SLIDING CONTACT BEARINGS

BEARINGS WITH SLIDING CONTACT.—Bearings which permit the moving parts to slide over them are called "sliding contact" bearings. There are two main types of these bearings, *i.e.*, step and journal.

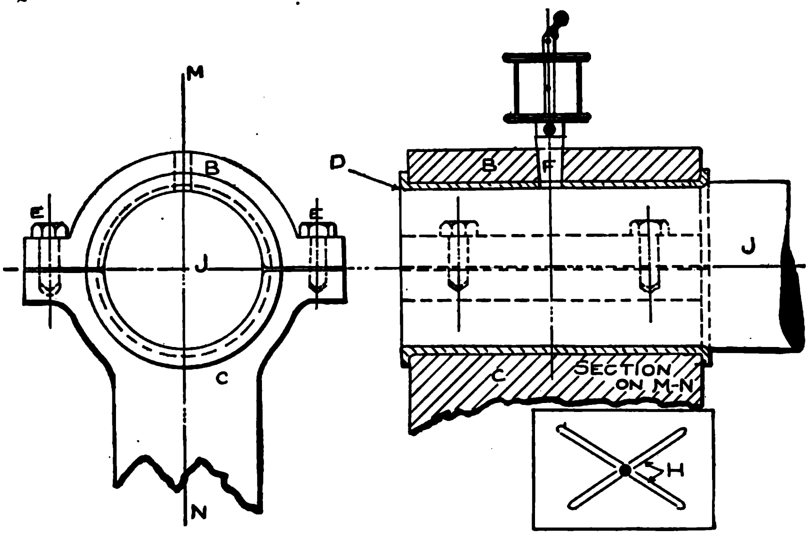


Fig. 2. Sec. 7a.—Journal bearing with sliding contact.

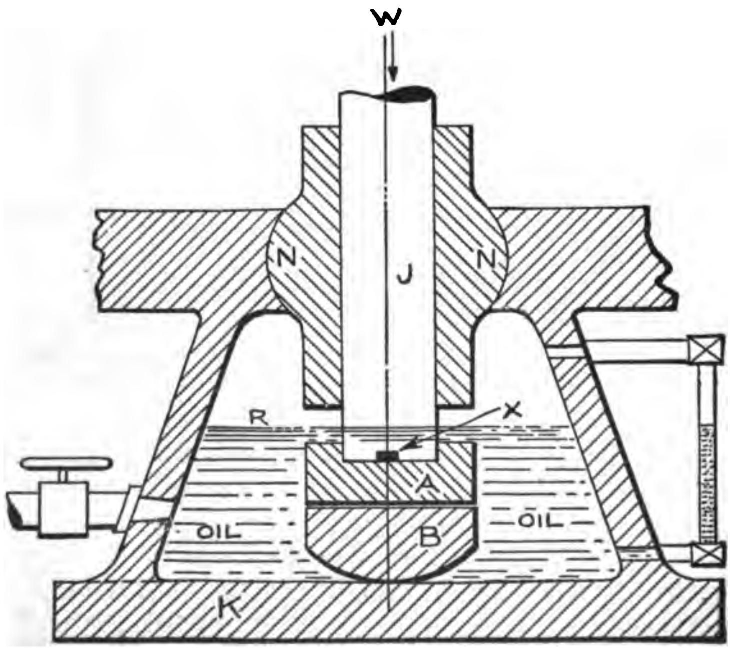


Fig. 3. Sec. 7a.—Step bearing with sliding contact.

JOURNAL BEARINGS.—A typical journal bearing is shown in Fig. 2, Sec. 7a. This type of bearing is in most general use and is the oldest type. It has many refinements in design to provide efficient methods of distribution for the lubricant. The names of the main parts of this type of bearing are given as follows, with letters referring to the figure:

B—Bearing cap.
C—Bearing.
D—Bearing lining metal.
E—Bearing cap bolts.
J—Journal.
F—Oil-feed hole.
H—Oil grooves, which are chipped in the surface of the bearing metal to improve the distribution of the lubricant.

STEP BEARINGS (SLIDING CONTACT).—A simple type of sliding contact step bearing is shown in Fig. 3, Sec. 7a. The parts of the bearing, as indicated by the letters in the figure, are given as follows:

J—Shaft.
B—Lower step bearing.
A—Upper step bearing.
X—Key, for holding the block in rotation with the shaft.
K—Casing, or bearing box.
R—Oil reservoir to allow the bearing to run in a bath of oil.

This type of bearing is in use for both low and high speeds, and is usually equipped with refinements for adjustments and oiling.

BEARING METALS

GENERAL.—Journal bearings, and sometimes step bearings, are lined with various bearing metals, which are different in nature from the metal composing the revolving or rotating parts which they support. It has been found that there is less friction between dissimilar metals in sliding contact than between like metals. For this reason bearing metal is usually different from that composing the rotating part. (This is excepted for hardened steel journals and bearings.) Another reason for using bearing metal is to provide a quick and easy method of replacing a worn-out bearing by inserting new bearing metal. If the frames of the machine and the journals ran in contact, the wear would be excessive, and when the bearing became worn it would be difficult and expensive to renew it.

Bearing metals are usually babbitt metal, phosphor bronze, gun metal, manganese bronze or brass.

Dr. C. D. Dudley, late chemist of the Pennsylvania Railroad, gave the following requirements and characteristics of a good bearing metal:

(*a*) It must have strength to carry the load without distortion.

(*b*) It must not heat rapidly.

(*c*) It must work well in the foundry. Oxidation causes spongy casting.

(*d*) It must have a low coefficient of friction.

(*e*) It must have a long wearing life.

BABBITT METAL.—The most generally used bearing metal for journal bearings is babbitt metal, used with soft steel journals. The original babbitt formula seems to have been: 89.3 per cent. tin, 3.6 per cent. copper and 7.1 per cent. antimony. The tin gives the required toughness and hardness, the copper gives the strength, and the antimony tends to make the alloy hard and brittle. Babbitt metal is a soft and fusible metal. It has special advantages over the hard bearing metals, due to the cheapness and ease with which a perfect bearing, in line with the shaft, may be made. Another advantage is the ease of renewal of a bearing with babbitt metal, it being melted and poured into place. Like other fusible bearing metals, babbitt in a melted state is run into the bearing box or shell, which is part of the machine frame, and into the bearing cap. The journal box holds the babbitt in shape about the journal.

There are many brands of babbitt metal on the market; some are good and some are worse than worthless. Ordinary babbitt metal varies greatly in composition, and often an unreliable dealer supplies refuse type metal for this purpose. The purchaser should buy only from reputable dealers, according to a definite formula, which has been found satisfactory for his use.

FORMULAS OF SOME BEARING METALS.—An approximate analysis of some bearing metals, some of which are proprietary, is as follows:

Approximate Analysis of Various Bearing Metals

No.	Name	Lead	Tin	Anti-mony	Copper	Zinc	Phosphorus
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1.	Ex. B. metal	15.00	8.00	.....	76.80	.....	0.20
2.	Ajax metal	11.50	11.50	.....	77.00	.....	0.25 of 15% P.
3.	No. 1 babbitt	80.00	20.00	.....	.....	.....	
4.	No. 5 babbitt	0.50	68.00	.....	1.0	30.50	
5.	Car-brass oil lining	84.87	.....	15.10	.....	.....	
6.	No. 1 bronze	11.5	11.5	.....	77.0	.....	
7.	No. 5 bronze	.....	15.0	.....	85.0	.....	
8.	Carmelia metal	15.0	4.5	.....	70.00	10.00	0.50 iron.
9.	Ajax plastic bronze	30.0	5.0	.....	65.00	.....	
10.	"S" bearing metal	9.5	10.00	.....	79.70	.....	0.80
11.	White metal	82.0	.....	12.0	6.0	.....	
12.	No. 3 babbitt	70.0	10.0	20.0	.....	.....	

Notes.—No. 10 is used as an acid-resisting alloy. The difficulties of making castings are increased in proportion to the increase in phosphorus. No. 1 is used for journal bearings for cars and in some cases for anti-acid. No. 9 is also used for car-journal bearings.

A bearing lined with bronze containing lead is said to be less liable to heat under the same condition of lubrication. Alloys containing a high percentage of antimony are suitable for use in heavy-duty machinery, as they are harder, while alloys containing a low percentage of antimony are adapted for high-speed machinery. Frictional resistance is less with alloys containing high percentages of antimony than is the case with low percentages.

HARD STEEL JOURNAL ON CAST-IRON BEARINGS.—Bearings of this manufacture have given good service. It has been found that the cast iron becomes glazed on the surface so that the friction between the bearing and journal is very low and the wear is very much reduced.

LEAD.—This is one of the most satisfactory bearing metals from an anti-friction standpoint, due to its soft yielding properties. Lead alone, however, is impractical for use in a bearing as a bearing metal, because it possesses no hardness or toughness. Therefore, it must be combined with some other metal to stiffen it.

CAST IRON.—In some bearings cast iron is used as a bearing metal. It must be a good grade of close-grained metal. Due to its granular nature, it seems to have the property of holding the lubricant in place. It is very brittle, however, and will not stand severe shocks without cracking.

OTHER BEARING METALS.—While soft bearing metals, such as babbitt, etc., are very generally used, there are certain classes of machinery which require a bearing metal having great toughness, hardness and

heat-resisting qualities. Railroads and rolling mills are particularly hard on bearings. In rolling mills, high temperatures and pressures are encountered, and only the hardest and toughest metals will stand the imposed conditions. Ordinary babbitt metal would soon be melted and run from the bearings. For railroad bearing requirements brass is largely used. Often the "brasses" are equipped with a crown of soft metal, set as a strip in the brass at the point of greatest pressure and wear. The soft metal takes up the wear, while the brasses give the required strength to the bearing.

BEARING METALS AND TIN CONTENT.—(Bureau of Standards, Tech. Paper 109.) The tin content of nearly all bearing metals can be reduced to some extent without affecting the service rendered. The Bureau of Standards has studied methods of conservation of tin alloys with particular regard to babbitt and bearing metals, bronzes and solders, and also considerable information was obtained from questionnaires sent to manufacturers and users of these materials. In cases where a breakdown will cause the greatest damage, and where the requirements are most exacting, high tin babbitt would be used, as, for instance, the main bearings of airplanes and military automobile engines, turbine shafts, etc., which would probably use high tin babbitt with a tin content of from 84 to 91 per cent. A babbitt metal, such as the S. A. E. No. 24, containing 84 per cent. of tin, 9 per cent. of antimony and 7 per cent. of copper, appears to be as satisfactory in service as genuine babbitt * * * 89 per cent. of tin, 7 1/2 per cent. of antimony and 3 1/2 per cent. of copper is that specified by the International Aircraft Standards Board * * * 91 per cent. tin, 4 1/2 per cent. antimony and 4 1/2 per cent copper. It should be pointed out that the latter two compositions are more fluid in the molten condition than the first-named, and consequently the lining can be made in a thinner shell with these babbitts, and the total amount of tin consumed may, therefore, be less than if the S. A. E. No. 24 were used. If the design of bearing is not ordered to admit of a thinner shell, the lower composition of babbitt should be used in general.

The following table is given by the Bureau of Standards Paper for use where a high grade of lining is desired, and where a genuine babbitt is often now used.

Ingredients	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Tin	65	62	8	5	10	21.3
Antimony	......	......	8	7	12.5	......
Copper	3–6	4	4	2	.5	3.0
Zinc	28–30	33	......	76	......	63.3
Aluminum	......	1	......	......	......	......
Lead	......	......	80	10	77	12

NOTE. Nos. 3 and 4 have been found to do the service required of tin base linings in machine tool bearings. No. 5 can be used on similar bearings where a greater strain is met. No. 6 is in use in Germany, as a "best" babbitt to conserve both tin and copper.

For linings on railroad truck journals, two compositions are in general use; one composed of 85 per cent. of lead, 10 per cent. of antimony, 5 per cent. of tin; and the other of 87 per cent. lead and 13 per cent. antimony. The latter is restricted by some roads for freight service, and the former is used on passenger equipment. Some roads use the 87 per cent. of lead and 13 per cent. of antimony on both classes of service.

LINING METAL, LEAD AND ALKALI OR ALKALI EARTH METAL.—(Bureau of Standards, Tech. Paper 109, March, 1919.) A type of lining metal is available that is composed almost entirely of lead, with small quantities of alkali or alkali earth metal. The Bureau of Standards has tested in service this type of bearing metal as compared with genuine babbitt of composition 89 per cent. tin, 7 1/2 per cent. antimony and 3 1/2 per cent. copper, and the following table is given showing the results of their tests:

GENUINE BABBITT

Load, pounds per square inch	Revolutions per minute	Total number of revolutions	Final temperature		Rise in temperature		Friction	Loss in weight	Remarks
			°C	°F	°C	°F	*Pounds*	*Grams*	
100	694	12 230	89	192	53	95	22	0.023	
200	706	16 510	102	216	58	104	29	.021	
300	682	15 150	125	257	100	180	38	.013	Belt slipping.
400	603	6 600	139	282	94	169	79	.054	Bearing seized and smoking

ULCO HARD METAL

100	710	13 160	56	133	23	41	13	0.013	
200	715	18 870	69	156	33	59	18	.021	
300	719	18 830	80	176	42	76	27	.013	
400	711	17 310	81	178	43	77	23	.022	
500	723	17 660	79	174	43	77	25	.014	
600	692	14 960	84	183	45	81	24	.021	
700	648	24 520	62	144	38	68	24	.020	
800	365	12 870	53	127	20	36	23	.010	
900	408	22 300	59	138	22	40	24	.015	
1000	405	23 200	66	151	36	65	22	.014	Bearing still in good condition

PHOSPHOR BRONZE COMPOSITIONS AND SUBSTITUTES.—(Bureau of Standards.) For bearings unlined. fairly high speeds and pressures, large quantities of phosphor bronze of the composition 80 per cent. copper, 10 per cent. lead and 10 per cent. tin, and deoxidized with phosphorus are used. The Bureau gives the following compositions as substitutes for the above, although they state that in their opinion trouble will sometimes be experienced with Nos. 8, 9 and 10, because of the high lead content, and they have about the same tin content as the others

on the list. The following table of compositions of substitute metals is given by the Bureau of Standards:

Ingredients	No. 7	No. 8	No. 9	No. 10	No. 11	No 12
Copper	81	79	74	64	Remainder	Remainder
Tin	7	5	5	5	8	5
Lead	9	15	20	25	15	17.5
Zinc	3	....	....	....	1.5–3	5
Antimony	....	....	....	5	....	....
Phosphor copper	....	1	1	1	....	....

STANDARD GRADES OF BABBITT METAL, WAR INDUSTRIES BOARD, CONSERVATION DIV., APR. 15, 1918, AND TIN CONSERVATION.—The Bureau of Standards report the results of its investigation in connection with four classes of babbitt metal ranging in tin content as follows:

A (genuine babbitt) .... 89 per cent. tin.
B .... 40 to 50 cent. tin.
C .... 4 to 6 1/2 per cent. tin.
D .... No tin.

They report on the above-numbered paper that it is impossible to restrict some of the classes to a single composition, because of the fact that several compositions of nearly the same tin content are in general use for different purposes. Thus, as is pointed out, No. A-1 in the table below is used in aircraft engines, No. A-3 is used for automobile engines and No. A-4 is found in bearings of electrical machinery. It was thought that where Class B could be used, Class C or Class D will be found to serve the purpose equally as well. There are, however, some grades of babbitt containing about 65 per cent. of tin which do not fall into either Class A or Class B, but which are often claimed by manufacturers to equal the high-tin babbitt in performance. If these claims can be substantiated, this babbitt should be considered as falling under the category of Class A, and as being a substitute for alloys of that class. * * * Alloy D-2 has been included in Class D because this comprises babbitt metals containing no tin. It should be noted that this alloy will be found satisfactory in many installations where Class A has hitherto been used, and its inclusion in Class D should not give the impression that it is a low-grade babbitt.

The American Society for Testing Materials has drawn up specifications for twelve compositions of babbitt metals (B23–18T), which do not take into consideration conservation of tin. * * *

In connection with its study of tin conservation, the Bureau of Standards gives the following compositions for the various classes, selected so as to include existing specifications and usage of babbitt metals as far as possible.

Class	No.	Tin	Antimony	Lead	Copper	Iron[a]	Arsenic[a]
		Per cent.	Per cent.	Per cent.	Per cent.		
A	A1	91	4½	[a] 1.00	4½	0.08	0.10
	A2	89	7½	[a] 1.00	3½	.08	.10
	A3	84	9	[a] 1.00	7	.08	.10
	A4	83	8½	1.00	8½	.08	.10
C	C1	5	10	85	[a] .50	......	.20
D	D1	......	13	87	[a] .50	......	.25
	D2	Lead about 98 per cent, balance alkali and/or alkali earth.					

[a] Maximum.

More than traces of impurities other than those listed above will not be allowed; the following variations above or below the specified amount will be permissible for the desired elements:

Per cent. of elements specified	Permissible variations over or under the specified value units of per cent.
Not over 5 per cent	0.50
5 to 10 per cent, inclusive	.75
Over 10 per cent	1.00

WHITE METAL VERSUS BRONZE.—(*Engineering*, Vol. 108, No. 2814): L. Archbutt found that under the same conditions of speed and pressure, and with the same oil, bearings of white metal would carry double the load of bronze bearings without increase of friction.

THEORY OF SLIDING CONTACT BEARING LUBRICATION

Every part of a machine which slides or moves oover another part instantly develops friction, and, unless the contact points or surfaces are separated by a film of lubricant, an excess of frictional heat and resistance will be developed.

The friction of lubricated surfaces varies greatly with the character of the lubricant and the method of application.

Professor Thurston has stated that a perfectly lubricated bearing has been found to be practically subject to the laws of fluid friction, while, as

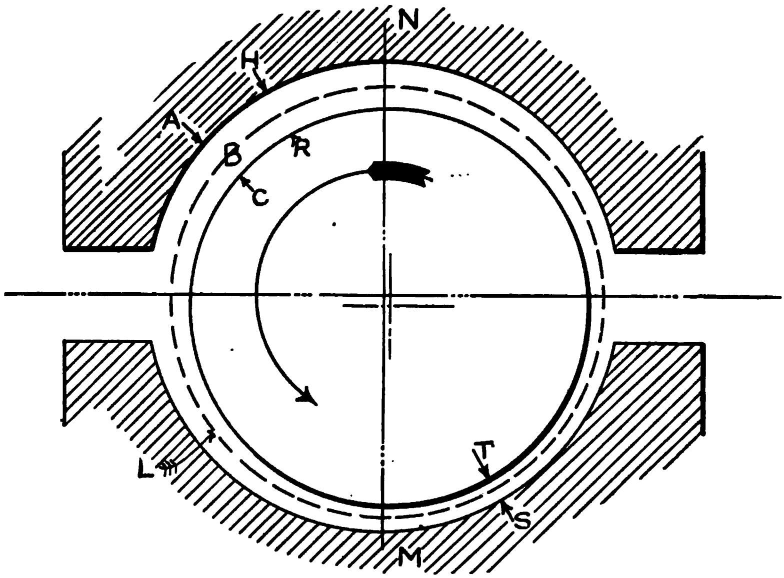


Fig. 4. Sec. 7c.—Journal and bearing.

the conditions in the bearing progress towards poor lubrication, the bearing approaches the conditions to which the laws of dry sliding friction apply.

THE "SLIDING LAYER THEORY."—Referring to the journal and its bearing shown in Fig. 4, Sec. 7a, we know that to obtain the least frictional resistance between the rotating journal and the bearing, it is necessary that the rotating part be "floated" by a film of lubricant, so that there will be no metallic contact between the surfaces.

The "*Sliding Layer Theory*" is based on the assumption that the lubricating film *L* is split into two or more layers, as shown at *A–B* and *B–C*. This division of the film into layers is due to the "*Adhesive*" action between the lubricant and the metallic surfaces of the journal and bearing, which is greater than the "*Cohesive*" attraction between the particles

composing the lubricant. Part of the layers, therefore, revolve relatively to the rotating journal, and the remaining layers tend to remain at rest, as is the surface of the bearing, so that a sliding movement takes place between the layers of the lubricating film. Since the frictional resistance between the oil layers is small, the frictional resistance of the bearing is reduced.

LANGMUIR'S THEORY OF LUBRICATING FILM.—This theory holds that the molecules of the oil and solid surfaces were held together by residual, or secondary valences (see index), and the more chemically active the lubricant, the more firmly it attached to the surfaces. (See *Engineering,* Vol. 108, No. 2814.) Dr. H. S. Allen, of Edinburgh University, referred to Langmuir's theory of films. as applied to lubrication as follows: The metal covers itself with a layer of oil one molecule thick, resembling a piece of velvet firmly glued to the metal with the pile outward, and two such velvet-clad surfaces would glide over one another with but little friction. If this be so, oiliness would depend neither on viscosity nor on compressibility, but on chemical forces and on the nature of both the lubricant and the metallic surfaces.

THICKNESS OF THE LUBRICATING FILM.—It has been demonstrated by experiment that the thickness of the lubricating film in a bearing is not uniform, but varies from an area of minimum to an area of maximum thickness, as shown in Fig. 4, Sec. 7a. This variation in the thickness of the oil film is due to the load on the journal and to the rubbing speed.

Referring to the figure again, the area *T–S* would be the area of "*Nearest Contact*" and the area *H–R* would be the area of "*Greatest Separation.*" The location of these areas has been found to shift with variations of rubbing speed and pressure of the journal.

PRESSURE IN THE LUBRICATING FILM.—Under normal loading conditions, the "Resultant Pressure" in a bearing is in a definite direction. Of course, under varying conditions of load and speed the resultant pressure shifts, but certainly it is at all times in a definite direction.

The pressure on the oil film must, therefore, be maximum at one point and minimum at another.

The "pressure of the oil film" itself has been found by various authorities to be independent of the journal speed and exactly proportional to the load on the journal.

The rotation of the journal "drags" oil from the area of low pressure and into the area of high pressure. When feeding oil into a bearing, it is necessary to overcome the film pressure present at the point of entry of the oil. It is due to the neglect of this fact that many oiling systems fail in their purpose, because the pressure head of the oil feed is lower than the film pressure at the point of entry. In some cases, the pressure in the oil film may be below atmospheric pressure and the bearing may actually suck oil into the film, if the point of entry is properly selected.

INTERNAL FRICTION IN THE LUBRICATING FILM.—As before stated, a lubricating film in a rotating bearing is composed of several layers of oil, and these layers are assumed to slip over each other at different relative speeds, with the result, that friction is generated between the layers and particles composing the film. This friction may be called "Internal Friction" and must be considered when summing up the total frictional resistance of the bearing.

* **VISCOSITY AND "BODY."**—The most important properties possessed by an oil with regard to bearing lubrication are *viscosity* and "*body.*"

The *viscosity* of an oil is a measure of the degree of its fluidity. It is that property of the oil that determines its rate of flow. The viscosity of a fluid is closely related to its internal friction, and the greater the viscosity the higher the internal friction.

The ideal lubricant for any bearing must possess *just* enough viscosity to enable it to maintain a lubricating film in that bearing for the set conditions of operation.

"*Body.*"—A good lubricant must possess the proper proportions of the properties of cohesion and adhesion in order that it may have the greatest efficiency. An excess of either is unsatisfactory. Mercury has an excess of cohesion and very little adhesion. Water has an excess of adhesion and a low proportion of cohesion. It is obvious that neither of these would be satisfactory as a lubricant.

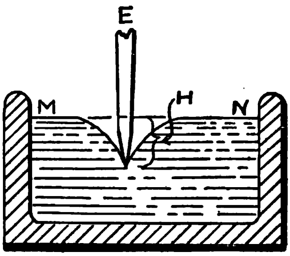


FIG. 5. SEC. 7a.—Surface tension.

Body is a property about which little real data have been obtained. It is, however, undoubtedly an important factor. At the present time several investigators are working on the subject.

"COHESION." — By Cohesion is meant that property of an oil that holds together the particles forming the oil. This property is of importance in the maintenance of the lubricating film, because the "Cohesive" properties resist the tearing apart or destruction of the film.

SURFACE TENSION.—The property possessed by fluids and known as "Surface Tension" has been advanced by several authorities as of the greatest importance in the maintenance of the oil film.

The Surface Tension of a fluid is due to the cohesive action of the particles composing the fluid. These cohesive forces act in all directions below the surface, and, since there are no forces tending to counteract them above the surface, the unbalanced condition produces a tenseness, or drumhead-like effect, at the surface. This tension causes the surface to resist to a greater extent any tearing apart of the particles composing it than is offered by the particles composing the body of the fluid.

Referring to Fig. 5, Sec. 7a, M–N is a fluid surface looking along it. If the needle E is pressed against the surface, as shown, it may be depressed a small distance H without breaking through the surface. This elastic property of the surface is due to Surface Tension.

The **durability of the lubricating film** depends on the following conditions:

(*a*) The velocity or rubbing speed of the journal.
(*b*) The cohesive properties of the oil.
(*c*) The unit load or pressure on the bearing.
(*d*) The temperature-viscosity characteristics of the oil.
(*e*) The capillary properties of the oil.

CAPILLARY PROPERTIES AND INTERFACIAL TENSION, LUBRICATING FILM.—Messrs. Henry M. Wells and J. E. South-

* NOTE. Also see index for Oiliness.

combe, of England, in explaining the principle of their patented process for lubricating oil, have developed some interesting data. They embody the following statements in their patent claims:

It has been recognized that for many purposes, mineral hydrocarbon oils do not lubricate so well as animal or vegetable saponifiable oils and fats. * * * We have discovered that the active principle, which enables such saponifiable oils to improve the lubricating properties of mineral oils is a relatively small quantity of free fatty acid, either pre-existing in the saponifiable oil, or formed therefrom by hydrolysis during lubrication. The principle of their invention consists in replacing relatively large amounts of saponifiable oil or fat (in a compounded lubricating oil consisting of a fatty oil compounded with a mineral oil) by a relatively minute amount of a suitable free fatty, or other organic, acid. * * * This principle is in direct opposition to prevailing views, it having been considered that free fatty acid is a constituent to be excluded from a lubricating oil, on account of the fear of corrosion. * * * A study of the capillary properties of various oils, using a drop pipette to measure the interfacial tension between oil and water, showed that saponifiable oils, or compounded oils, have a low interfacial tension against water. The low interfacial tension being due to the pressure of small quantities of free fatty acids, concluding that the efficacy of the saponifiable oils depended upon their free-acid content. * * * Accordingly, they added free fatty acid alone to a mineral oil, and state that the lubricating properties were improved, the interfacial tension against water lowered, and the danger of corrosion minimized. The free acid used, preferably free fatty acid, *e.g.*, commercial olein containing 95 per cent. free acid and, or whale-oil fatty acids, either hardened or not, in quantities of 1 per cent. to 2 per cent. to the mineral oil. In theory, the process depends on the principle that lubrication is a function of the capillary properties of the oil. A satisfactory lubricant must "wet" the bearing surface so that a thin film of lubricant will tend to move in to the constricted areas of high pressure. In practice, the bearing surfaces are usually contaminated with a film of moisture, and there is liability to form oxide films. The action of the free acid is to lower the interfacial tension between oil and water and apparently to allow the oil to displace the water film from the bearing surface. The chemical affinity between the acid and the metallic surface, or the oxide film (if present), runs parallel with a similar reduction in interfacial tension.

These gentlemen further state, in explanation of their theory: The action of the free fatty or other acid depends upon its molecular weight. If any acid of very low molecular weight, such as butyric acid, is used, it will exert a deëmulsifying effect, and we can, therefore, apply our process to produce non-emulsifying oils. * * * On account of the low molecular weight, these acids are much more active, and it is not desirable to exceed the limit of 1 per cent. * * * On the contrary, certain fatty acids of high molecular weight possess the property of increasing the emulsibility of hydrocarbon oils. * * * Thus highly unsaturated acids of high molecular weight are especially active. This is probably associated with polymerization and soap formation. * * * Any hydrocarbon oil may be used, *e.g.*, from petroleum, coal tar, shale, colophony, etc. The fatty acids used may be obtained from any class of saponifiable oil, fat soap and recovered grease. We may also use the

so-called naphthenic acids, or other acids obtained or manufactured from raw petroleum, shale or coal tar, or colophony. * * * Typical examples are given as follows: Two per cent. of commercial olein (fatty acid) is incorporated with a mineral lubricating oil. A product claimed to resemble closely a compounded oil containing 10 per cent. to 20 per cent. of olive oil, lard oil or tallow. * * * A concentrated compound may be prepared containing equal weights of commercial fatty acids and mineral oil by warming and mixing the ingredients. This concentrated compound is added to a hydrocarbon oil to the extent of 3 per cent. by weight (= 1 1/2 per cent. of fatty acid). * * * A non-emulsifying oil is prepared by adding 0.8 per cent. of butyric, cinnamic or an oil-soluble sulphonic acid to hydrocarbon oil. Certain naphthenic acids also exert this deëmulsifying effect. * * * An emulsifying oil suitable for marine lubrication is produced by this process, by adding 1 per cent. of the acids obtained from rape oil or wool grease and the like to a viscous hydrocarbon oil. * * * A mineral oil of high viscosity is treated with 2 per cent. of the commercial acids from castor oil, or even with 2 per cent. of olein. The product is said to be similar in properties to castor oil at relatively not too high temperatures and to be suitable for airplane-engine lubrication.

BEARING HEATS

THE COEFFICIENT OF MECHANICAL FRICTION.—The coefficient of mechanical friction, with respect to bearing lubrication, is affected by, and is dependent upon, many conditions. The steadiness of the bearing pressure and the nature of the motion have much influence on the mechanical friction of a bearing. The form of the surfaces of contact—whether flat or cylindrical—and the character of their contact—whether a surface, point or a line—are all factors affecting the coefficient of mechanical friction.

For any two metals of the same character of surface, the same lubricant and pressure, the coefficient of friction is far from being constant. For example, in a high-speed engine of the reciprocating type the allowable bearing pressures permitted by good engineering practice, for each square inch of bearing surface (projected area), may be roughly given as follows:

1. Cross-head guides	150 pounds
2. Shaft bearings	400 pounds
3. Cross-head pin	1200 pounds
4. Crank pin	600 pounds

It is evident that, although the metals in contact are usually the same and the character of the surfaces is identical, nevertheless the allowable unit pressures for these bearings differ in each case. These wide differences are due to the fact that it is necessary to work with a different factor of safety for the coefficient of friction for each case.

WORKING HEAT.—A bearing is so proportioned that at its maximum pressure and rubbing speed its temperature, with good lubrication, shall not rise above a " working heat," so that seizing shall not occur, due to expansion.

FRICTIONAL HEAT.—The energy consumed in overcoming kinetic frictional resistance is converted into heat. This heat is called Fric-

tional Heat, and may be considered a measure of the energy wasted in overcoming friction.

BEARING PRESSURES AND LUBRICANT FILMS

BEARING PRESSURES.—Some approximate pressures per unit area of bearings designed for various purposes may be obtained from the following table. When considering the lubrication requirements of any of the following-named bearings, the maximum pressures should be used, in order to provide a good margin of safety.

ALLOWABLE PRESSURE PER SQUARE INCH FOR VARIOUS BEARINGS AS INDICATED

U. S. Navy:	
Main engine bearings	275– 400 pounds per square inch
Main engine crank-pin bearings	400– 500 pounds per square inch
Steam turbine bearings	85 pounds per square inch
Thrust bearings	50 pounds per square inch
Merchant Marine:	
Main engine bearings	400– 500 pounds per square inch
Main engine crank-pin bearings	400– 500 pounds per square inch
Slow-speed Stationary Engine:	
Main bearing (dead load)	80– 140 pounds per square inch
Main bearing (steam load)	200– 400 pounds per square inch
Crank-pin bearings	800–1300 pounds per square inch
Cross-head pin bearings	1000–1500 pounds per square inch
High-speed Stationary Engine:	
Main bearings (dead load)	60– 120 pounds per square inch
Main bearings (steam load)	150– 250 pounds per square inch
Crank-pin bearings (overhung crank)	900–1500 pounds per square inch
Crank-pin bearings (centre crank)	400– 600 pounds per square inch
Cross-head pin bearings	1000–1800 pounds per square inch

PRESSURE EFFECT ON VISCOSITY.—Undoubtedly the viscosity of lubricating oil is affected by pressure. No definite data have been obtained on this subject. However, it is known that the viscosity of water is decreased, and that of a concentrated salt solution is increased, by increasing the pressure. The *unit pressure* upon the bearing, the bearing speed and the oil-feed pressure are the determining factors which should be used in selecting an oil for use in any bearing from the viscosity standpoint.

THICKNESS OF LUBRICATING FILMS.—The thickness of the lubricating film that is formed with oil lubrication is dependent upon the following factors: The viscosity of the lubricant, the speed of the bearing, the shape of the bearing surfaces, the area of the bearing and the load.

Designers of bearings should make provision for supplying a definite amount of oil for each 100,000 square feet of bearing surface rubbed over.

ANIMAL AND MINERAL OILS, LUBRICATING FILMS.—* Mineral oils do not have the same faculty for forming thick, permanent films as do animal and vegetable oils. Therefore, for heavy loads and small bearing surfaces compounded oils or greases are the best.

* NOTE. See index for Free Fatty Acid and effect upon interfacial tension of lubricating films.

BEARING CHARACTERISTICS

SPEED-FRICTION CURVES.—The curves shown in Fig. 6, Sec. 7a, illustrate the effect upon the coefficient of friction by increasing the speed of the journal when lubricating with mineral oils of various viscosities (Saybolt).

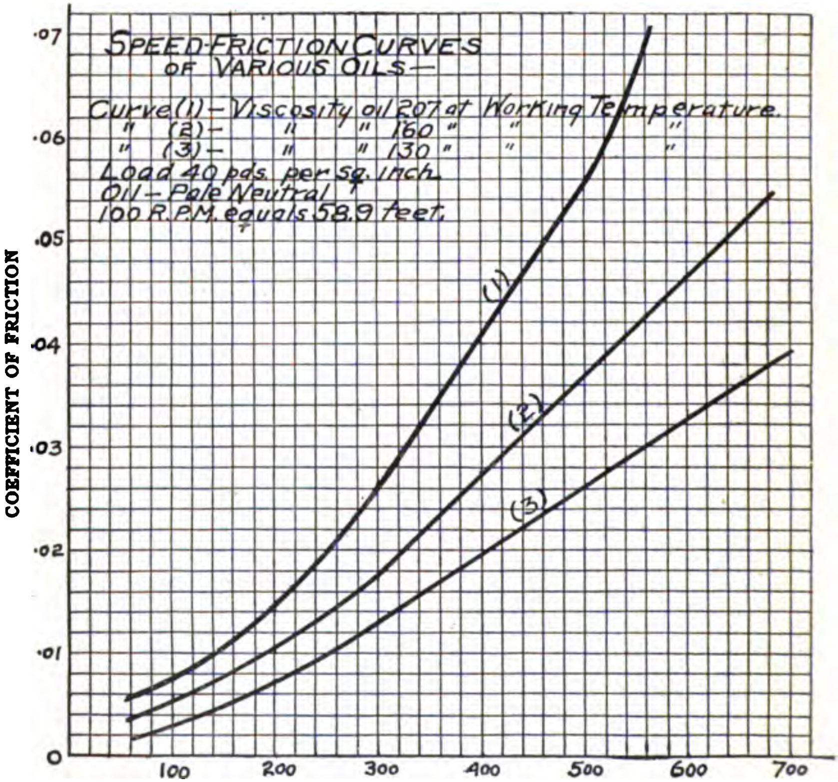


Fig. 6. Sec. 7a.—Speed-friction curves.

FEED-FRICTION CURVE.—The curve shown in Fig. 7, Sec. 7a, shows the effect upon the coefficient of friction produced by increasing the feed of the lubricant. It is very clear that at a definite point an increase in feed does not produce any reduction in friction. Thus we might say the "saturation" point of the bearing is reached at that point.*

VISCOSITY-BREAKDOWN POINT CURVE.—Fig. 8, Sec. 7a, shows the relationship between oil viscosity and breakdown pressure.

* For that particular oil.

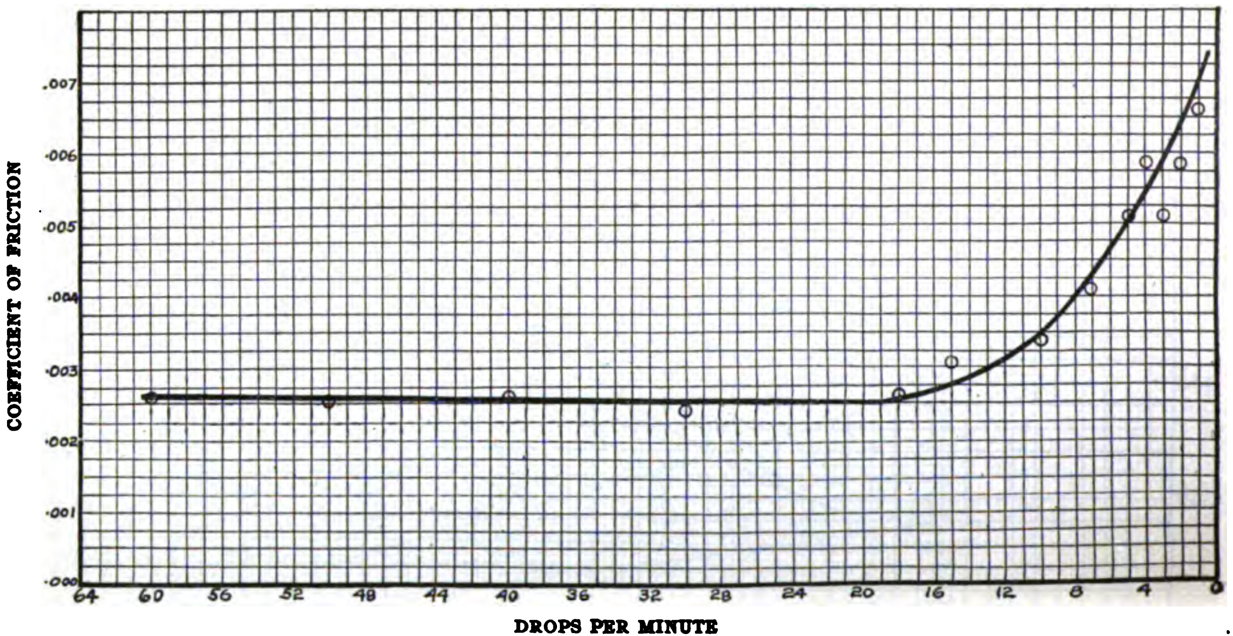


FIG. 7. SEC. 7a.—Feed-Friction curve; Load 74 pounds per square inch; Speed 300 r.p.m.; Temperature 100° Fahr. (Mineral Oils.)

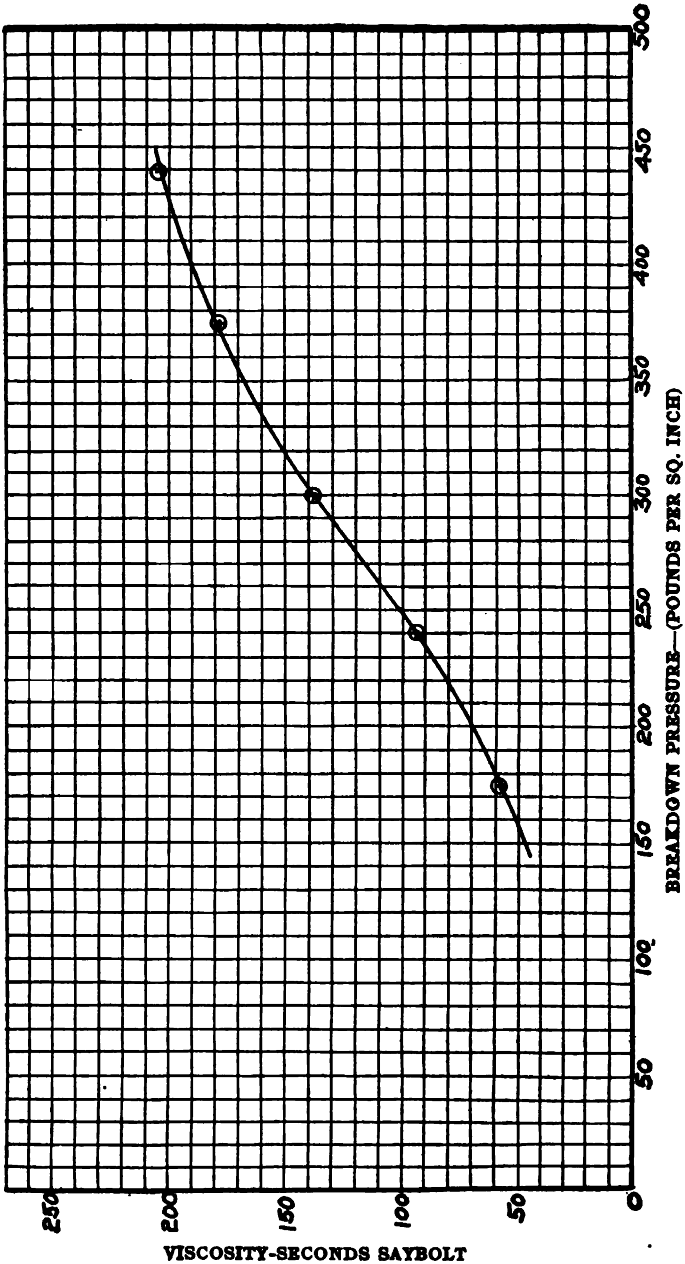


FIG. 8. SEC. 7a.—Breakdown curve. Speed 300 r.p.m.; Temperature 100° Fahr.; Feed 40 drops per minute. (Mineral Oils.)

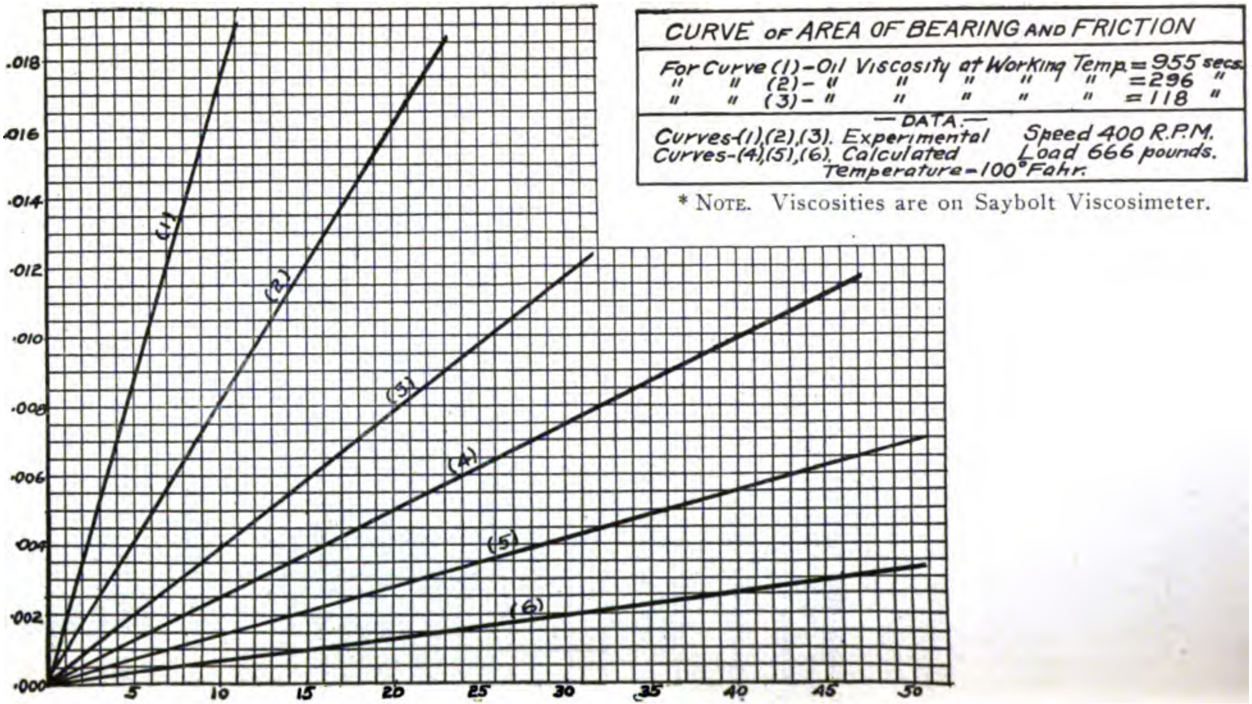
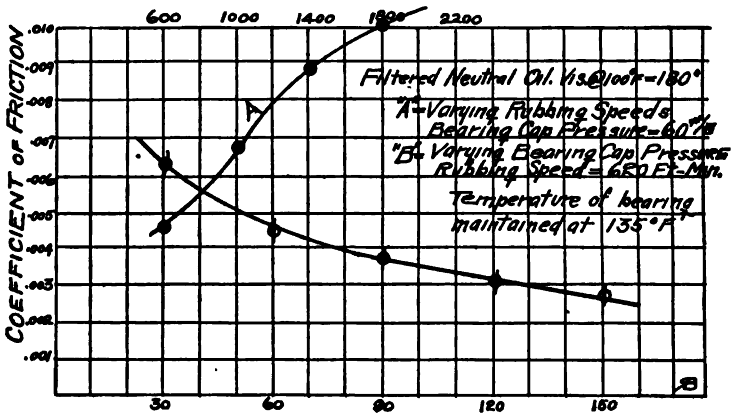


FIG. 9. SEC. 7a.—Area of bearing and friction curve. (Mineral Oils.)

AREA OF BEARING AND FRICTION CURVE.—The effect of increasing the area of the bearing upon the friction produced in the bearing when lubricated with oils of various viscosities is clearly shown in the curve of Fig. 9, Sec. 7a. Curves 1, 2 3 were determined by experimental results, and curves 4, 5, 6 were fixed from calculated results.

BEARING-CAP PRESSURE AND COEFFICIENT OF FRICTION.—Fig. 10, Sec. 7a, shows the effect upon the coefficient of friction

JOURNAL RUBBING SPEED (FEET-PER-MINUTE)



BEARING CAP PRESSURE—POUNDS PER SQUARE INCH

FIG. 10. SEC. 7a.—Curves showing relation between rubbing speeds, bearing cap pressures, and coefficients of friction. (Mineral Oils.)

when the pressure on the bearing is increased, while the speed and temperature are kept constant.

When designing the *radiating capacity of a bearing*, a maximum temperature rise of 50° Fahr. above room temperature is a fair average for heavy, slow-speed bearings, and about 75° Fahr. for light, high-speed bearings.

SEMI-DRY FRICTION

GENERAL DATA.—F. Zur Nedden in discussing a paper by M. D. Hersey on the "Laws of Lubrication of Journal Bearings" states: "When gradually reducing at a constant pressure (p) the speed of any bearing, the coefficient of friction, in the neighborhood of zero, after reaching a minimum, abruptly increases to a high figure, because with very low speeds liquid friction is giving way to semi-dry friction. * * * The point where this change occurs depends partly upon the smoothness of the gliding surfaces. * * * Toothed wheels running in oil will show lesser friction losses if designed so that the flanks of the teeth glide on each other, with a speed exceeding the upper limit of semi-dry friction."

H. F. Moore, in a discussion of the same paper as above mentioned, states: "Experiments made with a bearing of babbitt metal on a steel journal showed that before the film of oil broke down the carrying power increased with some function of the speed, and so far as the tests went, the bearing power was found to vary approximately with the square root of the speed. Later tests made at the University of Wisconsin on very carefully ground, hardened steel journals, rotating in bronze bearings, showed a carrying power two or three times as great as did the babbitt metal bearing with unhardened journals. It might be expected that surface finish of the journal and bearing would play a very important part in determining the breaking strength of the oil film."

BEARING CLEARANCES

RUNNING CLEARANCE.—Bearings may be adjusted for a "running clearance" (that is, clearance enough to allow for smooth running, with the bearings and journal at normal running temperature), or they may be given enough clearance, so that should they run hot from any cause, the expansion of the journals and bearings will not be sufficient to cause them to grip and bind. Since pounding frequently accompanies "expansion clearance," it is usual practice to adjust for running clearance only.

The **running clearance** of the ordinary engine main bearing is only about 0.009 of an inch for a six-inch to a twelve-inch shaft. When the shaft revolves and the lubricating film is broken into several layers, it can easily be appreciated that the thickness of the individual layers must be very thin. We must consider that it is the cohesive resistance to tear within the body of the lubricating layers, rather than the increased elasticity of the surface of the layers, that is the deciding factor in the maintenance of the lubricating film in combination with surface adhesion.

ALLOWANCE FOR OIL BETWEEN SHAFT AND JOURNAL.—The following table gives the allowance for oil between shaft and journal in medium- and high-speed bearings, as contained in an article on bearings by Edward K. Hammond, printed in the July, 1918, *Machinery.*

Diameter of journal	Allowance
3/8 to 1	0.002
1 1/8 to 2 1/2	0.003
2 5/8 to 3 1/2	0.004
3 5/8 to 4 1/2	0.005
5	0.006
5 1/2	0.007
6	0.009
7	0.011
8	0.012

As will be noted, the allowance varies with the diameter of the shaft.

BEARING OIL GROOVES

GENERAL DATA.—Oil grooves are cut into the surface metal of bearings to improve the distribution and efficiency of the bearing lubricant. It has been the general custom in the past to cut oil grooves in both the top and bottom sections of the bearings, but experience has indicated that better results can be obtained by cutting the grooves in the upper half of the bearing only. Nothing should interfere with the suction of the oil from the low-pressure area to the area of high pressure, and it is a law of fluid friction that the friction between a solid and a fluid is increased with an increase in the roughness of the solid surface. For this reason, the "pull" of the journal surface, due to the adhesive effect between the oil and the journal, may be largely offset by oil grooving in the lower bearing surface.

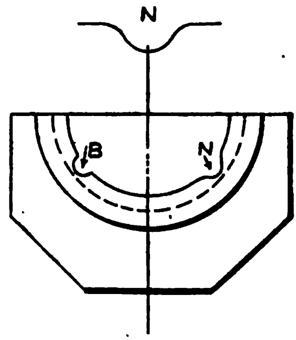


FIG. 11, SEC. 7a.—Oil grooves.

Oil grooves should be at right angles to the direction of motion of the revolving or sliding part. The grooves should always be cut to a point a short distance from the outer edges of the bearing—never to the edge.

Oil grooves are expected to perform the following functions:

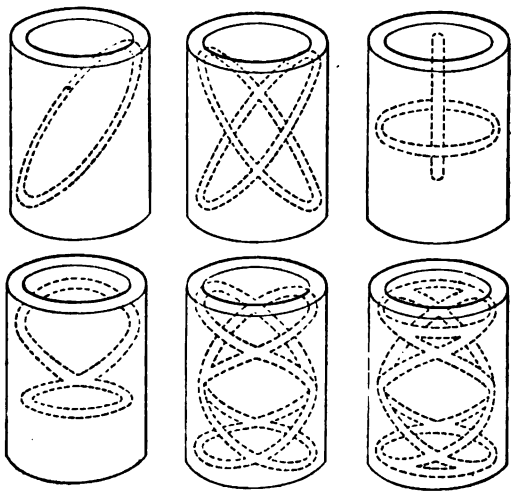


FIG. 12. SEC. 7a.—Different forms of oil grooves in bronze bushings.

1. To hold the lubricant in the bearing.
2. To distribute the lubricant in a lateral direction (that is, sideways) over the surface of the bearing.

3. To return the lubricant that works over to the edge of the bearing towards the centre.

There should be no sharp edges where the bearing is cut to make an oil groove, as these edges increase the wiping effect and may act as scraping edges. If the edges of the grooves are rounded, as shown at (*N*) in Fig. 11, Sec. 7a, the wedges formed aid in the flowing or wedging of the lubricant between the bearing surface and the journal. An incorrect or sharp-edged oil groove is shown at (*B*).

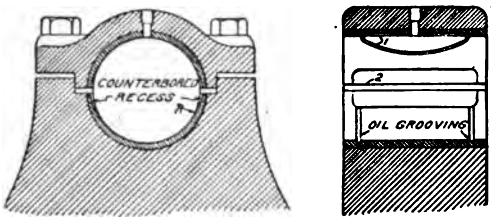


FIG. 13. SEC. 7*a*.—Oil grooving and counterbored recess of outboard bearing.

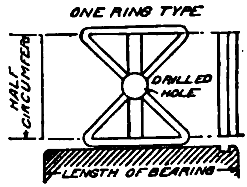


FIG. 14. SEC. 7*a*.—Single ring oiled bearing. Oil groove layout. (Courtesy Power Plant Engineering.)

Special machines are made for cutting oil grooves, which give quicker results than would be possible with hand tools. There are several reasons for cutting oil grooves of the spiral type, such as are shown in Fig. 12, Sec. 7a, instead of grooves that are straight and parallel with the axis of the journal. One of these reasons is the tendency for the oil to gather

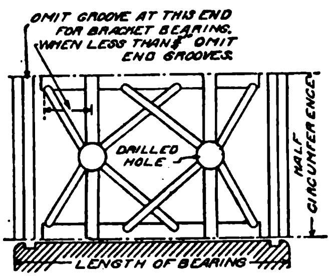


FIG. 15. SEC. 7*a*.—Double ring oiled bearing. Oil groove layout.

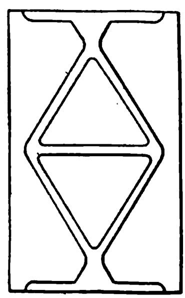


FIG. 16. SEC. 7*a*.—Crosshead shoe oil groove. (Courtesy Power Plant Engineering.)

in the grooves at the bottom of a bearing, while those at the top would be empty. In the case of the spiral grooves, the rotation of the journal has the tendency to circulate the oil through the grooves.

OIL GROOVE NOTES.—(*Power Plant Engineering*, December 15, 1918, p. 957.) Fig. 13, Sec. 7a, shows a plan for distribution of the lubricant, when the lubricant is fed through a hole in the bearing cap. In the lower half of the bearing only shallow grooves, parallel to the ends of the shell, are cut, these being intended to retain the oil.

Fig. 14, Sec. 7a, shows oil grooves for single, ring-oiling bearings.

Fig. 15, Sec. 7a, shows oil grooves for double ring-oiling bearings.

The depths of the above grooves range from 3/32 inch to 5/16 inch, depending upon the size of the bearing.

Fig. 16, Sec. 7a, shows the arrangement of oil grooves for crosshead shoes. The grooves are arranged in the form of a diamond, the lines crossing from 1 to 2 inches from the end, and cut to a depth of about 3/16 inch and 1/4 inch in width. It is intended that when the engine is in operation the open spaces at the ends of the diamond of the lower shoe collect the oil lying on the bottom side, and, due to the travel of the crosshead, force it out through the grooves to the other side, when the operation is again repeated. One of the objects obtained is a reduction of splashing. It is not necessary to cut oil grooves in the boxes of crank-pins. The edges where the boxes curve together should be counterbored. The crankpin itself is provided with a duct, drilled through the pin proper. A shallow groove or flattened space is cut in the surface of the pin parallel to its axis and reaching almost to the end of the pin. The oil enters through the duct in the pin.

THE EFFECT OF AIR BUBBLES IN LUBRICATING OIL.— An English engineer has investigated the creeping of oil over the outside surfaces of bearings, and the results of his findings are included below without comment as to their merits.

He states as follows: "Oil used as a lubricant creeps over the outer surfaces of a bearing, even at ordinary temperatures, due to the fact that air is drawn into the oil by the rotative action of the journal and due to the rapid flow of the oil in the feed pipes. This air spreads through the body of the oil in the form of finely divided bubbles. These bubbles burst when they come to the surface and form a fine spray, which settles on the exterior of the bearing, causing a resulting waste of oil." * * *

"The investigator recommends that the return pipes from bearings be made oversize and large enough to carry off the expanded volume of oil and bubbles, or that a vent pipe, opening out at a higher level than the oil supply tank, be provided to remedy the trouble."

"HOT BOXES"

HEATED BEARINGS, EFFECT ON OIL FILM.—When a bearing tends to run hot, the oil film is difficult to maintain. It tries to shrink and leave the bearing surfaces dry. This action is probably due to the surface tension of the lubricating film being reduced in strength or tension by heat, so that the oil is pulled towards the cooler parts of the bearing, where the surface tension of the liquid is greater.

HEAT LIBERATED BY BEARINGS.—The formula generally used for heat liberated by any bearing surface, which is proportional to the friction is as follows:

$$\text{Thermal units generated per minute} = \frac{W \times F \times V}{778}$$

Where W = Total pressure in pounds on rubbing surfaces.
F = Coefficient of friction.
V = Rubbing speed in feet per minute.
778 = Mechanical equivalent of heat.

CAUSES OF HOT BEARINGS OR "BOXES."—A "hot box" or overheated bearing may be due to any one of several causes, as follows:

(*a*) The bearing may be receiving an insufficient amount of oil.

(*b*) The journal shaft may be "out of line."

(*c*) The lubricant may be unsuitable.

(*d*) In the main bearings of engines overheating may be caused by too little compression in the steam cylinder, which should act as a cushion for the inertia of the reciprocating parts at the end of the stroke. When this compression is lacking, the oil film is subjected to alternate high and low pressures, which tend to impair its uniformity.

REMEDY FOR HOT BOXES.—The first step in the adjustment of a hot box is to loosen up the bearing all around; then give it a generous supply of oil through the oil hole, or feed the bearing a mixture of one part graphite and ten parts of heavy engine oil.

WARM BEARINGS.—There is no reason to expect that a bearing should run cold, and in a normal bearing the temperature will rise to a point where the rate of heat being produced in the bearing is just balanced by the rate of radiation of this heat by the metallic parts to the surrounding air, plus the heat carried away by the oil and the engine frame. Those in charge of engines should familiarize themselves with the various normal running temperatures of the bearings of the machines under their care. Large machines and high-speed equipment should be provided with thermometers on the bearings, to indicate the running temperatures.

CLEARANCE FACTOR.—If a bearing is to be provided with clearance to prevent binding, a "clearance factor" should be used.

The diameter of the journal, multiplied by the coefficient of expansion of the metal composing it, and the probable range of temperature under running conditions, will give the clearance diameter for the bearing.

WATER.—Sometimes a stream of water is run on an overheated bearing or crank-pin to cool it off. This should never be done, except as a last resort, and only in cases where the engine must be kept running at all costs, until such a time when it may be shut down for repairs. Serious distortion will probably result from this practice.

BABBITTED BEARINGS.—These bearings should be examined after a hot box, because the oil feeds may be clogged, or at least partly clogged, by melted metal. If trouble from overheating occurs in a babbitted bearing, it should be opened, and any spots that appear to be darker than the rest of the bearing should be scraped, as these are the high spots.

BRASS AND BRONZE BEARINGS.—If a hot box occurs in a brass or bronze bearing, it will probably be distorted by the heat and should be refitted. Coat the journal surface with red lead and apply the brasses, and then slide them around the journal. The high spots on the brasses will be indicated by red lead sticking to them. These spots should be scraped and filed, until the whole surface of contact is covered with red lead when the brasses are applied to the journal as above described.

GREASE LUBRICATION

THEORY OF GREASE LUBRICATION.—The resistance to shear of a plastic lubricant, such as a cup or engine grease, at low speeds, may be less than that offered by an oil film. This is due to the fact that the grease film is thicker and the rate of distortion is, therefore, less than with the oil film.

When the bearing load is heavy and the bearing surfaces are forced together, an oil film is forced out of the bearing and metallic contact will occur. With a grease, as the surfaces approach, the shearing action decreases until a point is reached, when "flow in the film" ceases, and the film will not become any thinner. Thus metallic contact is prevented. This feature of grease lubrication is an important factor governing the selection of greases for lubrication, particularly for those bearings which are operated at low speeds and high pressures, especially where the bearing may be at rest for some time. Here the starting friction must be overcome when the bearing surfaces are again given relative motion.

The importance of the effect of the thickness of the lubricating film must be emphasized. (See index for other references to thickness of lubricating film.) If all surfaces in bearings were perfectly smooth, there would be no tendency for the projections to interlock. Since this is not possible, however, it must be appreciated, that with oil lubrication the lubricating film may become so thin, that when the relative rubbing motions of the surfaces are low, or when the surfaces are at rest, while they do not actually touch, they do to some extent interlock. This causes the starting friction to be larger than the friction of motion.

When grease is used as a lubricant under the above conditions, the film between the surfaces of the bearing will not allow its being pressed to thin enough dimensions to permit interlocking. The starting friction with grease is, therefore, a factor depending upon the shearing resistance offered by the film.

GREASE FRICTION TESTS.—The Engineering Experiment Station of the University of Missouri, in Bulletin Vol. No. 4 and No. 4, reports a series of friction tests made on various oils and greases by A. L. Westcott, which are abstracted* as pertaining to lubricating grease, as follows. The tests were made on the Golden Oil Testing Machine, as described elsewhere. (See index.) Three series of grease tests were made:

Series A: Tests of cup grease of different densities, using a hand-operated grease cup, with intermittent feed; using bearing shown in Fig. 38, Sec. 6.

Series B: Tests of same greases as used in Series A, but using bearing shown in Fig. 39, Sec. 6, and using a grease cup having a constant feed.

Series C: Tests of six different greases, to determine their behavior when applied in a grease cellar on top of the journal, with a view to their flowing into the bearing by gravity when warmed.

Greases from two makers, designated as X and Y, were tested in series A and B. Greases from six different makers, designated by numbers 1 to 6, were tested in Series C.

The consistency of the X greases is indicated by a number; No. 00 being the hardest, No. 6 a semi-liquid, and the other numbers forming a graduated series between. The Y greases are likewise numbered, the hard grease having the highest number, while No. 1 is very soft. No. 5 Y is about the same consistency as No. 00 X.

The greases in Series C are described as follows:

No. 1—Soft; spongy, fibrous; bright yellow.
No. 2—Hard; bright yellow.
No. 3—Soft; dark brown.
No. 4—Very hard; light brown.
No. 5—Extremely hard; looks and smells like soap.
No. 6—Graphited grease; soft.

Mr. Westcott brings out the following results which are of particular interest: The best results * * * were obtained when using a grease cup with a plunger actuated by a helical spring, so as to give a constant feed. When adjusted to feed grease steadily and uniformly, the coefficient of friction at a given load and temperature remained about constant. With intermittent feed with the hand-operated cup, results were not so good as when observations were taken immediately after feeding the grease, and at one-minute intervals thereafter the friction was seen to steadily increase, * * * decreasing again to its former value upon again forcing the grease.

The curves shown below are taken from Mr. Westcott's paper and are very interesting.

Curves shown in Fig. 17, Sec. 7a, and Fig.. 18, Sec. 7a, are for X grease, No. 3 density, series A, loads 46 to 148 pounds per square inch. Diameter of journal, 2 5/8 inches; length, 1 1/2 inches. Compression cup used, with intermittent feed of lubricant.

Curves shown in Fig. 19, Sec. 7a, and Fig. 20, Sec. 7a, are for X grease, No. 3 density, series B, loads 53.5 to 153.8 pounds per square inch. Diameter of journal, 1 1/4 inches; length, 2 inches. Grease cup, with spring-actuated plunger.

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* By special permission.

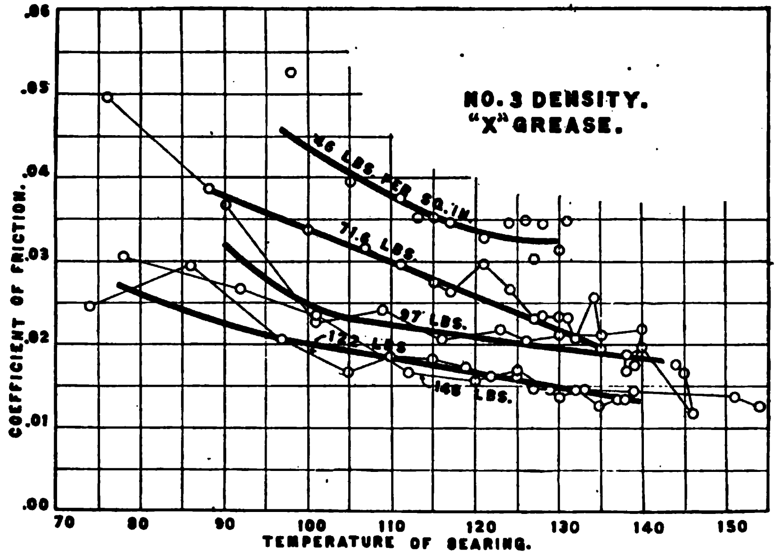


FIG. 17. SEC. 7a.

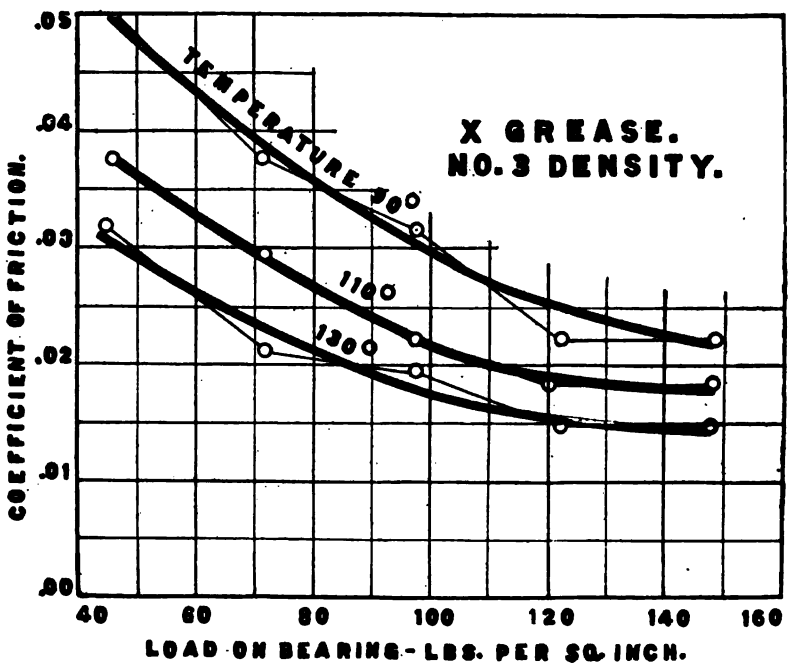


FIG. 18. SEC. 7a.

The curves shown in Fig. 21, Sec. 7a, and Fig. 22, Sec. 7a, show the final set of data derived by Mr. Westcott as to X grease, series A and B; for a selected bearing pressure and temperature, the coefficient of fric-

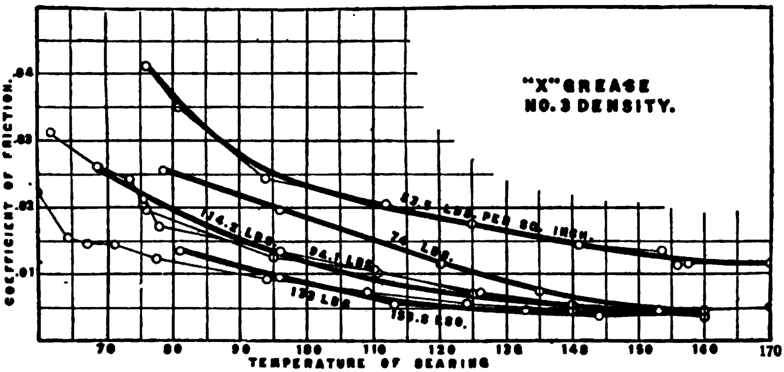


FIG. 19. SEC. 7a.

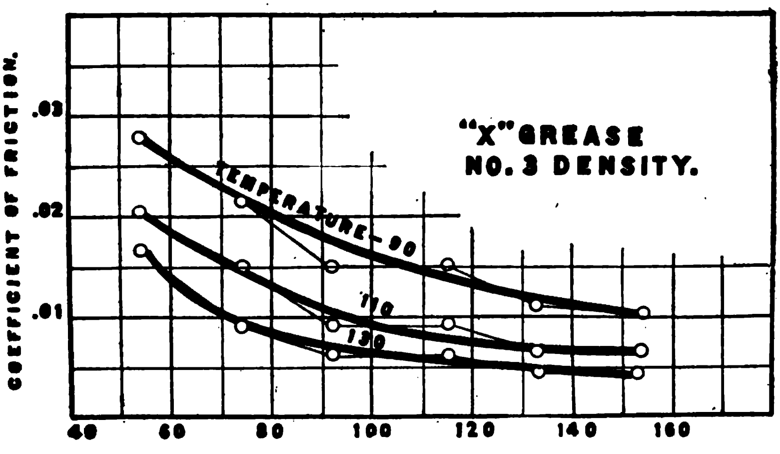


FIG. 20. SEC. 7a.

tion of each grease number was plotted against the grease numbers, * * * the purpose being to show the most advantageous grease consistency for various conditions.

As a result of his observations Mr. Westcott states: "Grease lubrication compares favorably with oil where the form of bearing is such as

to favor the retention of the film of lubricant and provision is made for an ample supply to the bearing. * * * Oil will give better results in a bearing which is short in proportion to its diameter. Grease of soft consistency is a much better lubricant than the harder densities of the

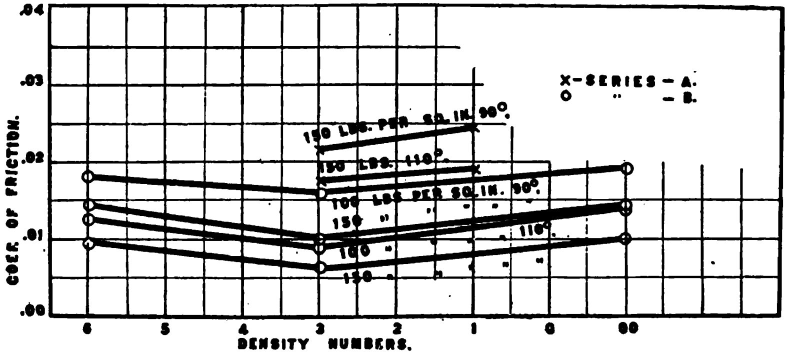


FIG. 21. SEC. 7a.

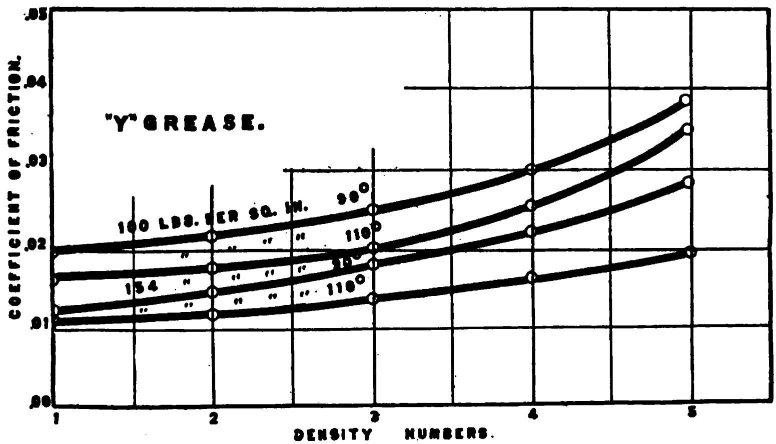


FIG. 22. SEC. 7a.

same grease." In this conclusion Mr. Westcott is in line with the accepted practice, which concludes that the real lubricating value of a grease is performed by the oil component of the grease, while the lubricating value of the soap content is slight. The softer consistencies contain a greater percentage of oil.

On the methods of grease application, Mr. Westcott concludes: "The best method of applying grease to a bearing is by a forced feed and a consistent rate of flow. This agrees with the best practice in oil lubrication, where the bearing is flooded with oil. * * * Grease cups with spring-actuated plunger are designed to give a constant rate of flow of grease. They are far from accomplishing this purpose, however. When such a cup is full of grease, the spring is compressed to its maximum amount, and the pressure upon the grease is, therefore, much greater than when the cup is nearly empty. Provision is made to regulate the flow by means of a small cock placed in the outlet of the cup, but this needs adjustment as the cup empties, and is apt to be neglected. * * * Experiments upon grease consistency show what a great difference in flow is produced by a small change in the pressure upon the grease. A design of cup is desirable which will deliver the grease at a constant rate from the time it is filled until it is empty."

SECTION 7b

BALL BEARINGS

Ball bearings are those in which the load is carried by a number of steel balls, very accurately finished and polished, which are held in place by grooved rings, called " races."

A radial ball bearing is shown in Fig. 1, Sec. 7b, and is designed to carry radial loads. Referring to the figure, *A* is the outer race, *B* is the inner race, *C* are the hardened steel balls, and *D* is the opening to permit the insertion of the balls.

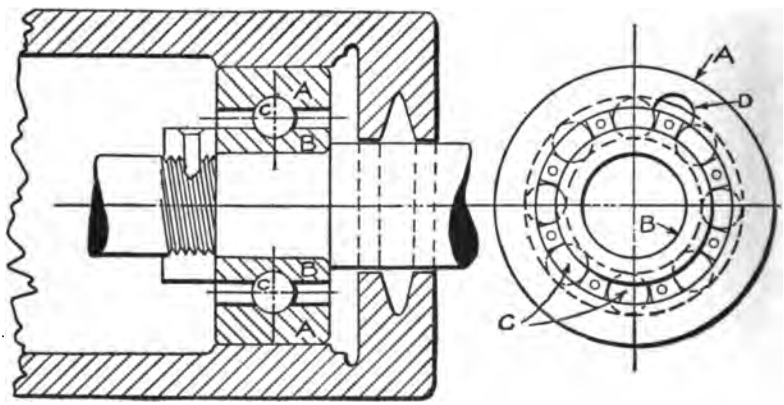


FIG. 1. SEC. 7*b*.—Radial ball bearing.

The load-carrying capacity of the bearing is directly proportional to the number of balls. To secure the full carrying capacity, the balls must represent as close an approach to true spheres as it is possible to realize. All of the balls must be exactly alike in size, because if one ball is larger than the rest it will receive more than its share of the bearing load, while an undersized ball will be underloaded. To secure an even division of the load, the balls should not vary more than one ten-thousandth of an inch in diameter.

BALL CAGE.—A " cage " is a small spacing block used to keep the balls separated, to reduce the noise of the bearing, and to obviate to a more or less extent certain forms of wear.

The noise made by radial ball bearings when running is caused by the removal of the load from the different balls as they roll through the area of maximum pressure and up to the point of no load. When a ball passes from the area of pressure it snaps forward against the ball in front of it and then against the outer race, causing a clicking sound. Ball bearings are also made with two rows of balls.

DIFFERENCE BETWEEN THE REQUIREMENTS OF LUBRICATION OF SLIDING AND ROLLING CONTACT BEARINGS.— The amount of friction developed by a journal or shaft with surface contact and sliding motion is larger or smaller, depending upon the efficiency of the bearing lubrication. This is true, because in sliding contact bearings there must be no metallic contact between the sliding surfaces if excessive friction is to be avoided.

In the case of roller or ball bearings, however, there is always metallic contact between the balls and the bearing surfaces. This contact is of a rolling nature, and for a ball bearing the contacts are points* and for a roller bearing the contacts are lines.

SPEEDS.—The speeds of roller and ball bearings can be carried very high, greatly exceeding any possible speeds for bearings with sliding contact. In the case of step or thrust bearings, carrying high loads, the maximum bearing pressure per unit load area, for sliding contact bearings, is much lower than the maximum loads permissible with ball or roller bearings.

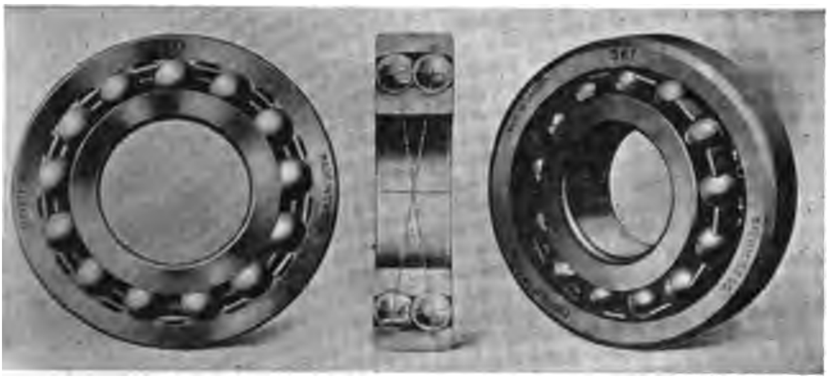


FIG. 2. SEC. 7b.—S. K. F. ball bearing, with pressed steel retainer, showing bearing in normal, deflected and sectional view.

SELF-ALIGNING BALL BEARINGS.—Self-aligning ball bearings differ from other types of ball bearings, in that they allow free shaft rotation no matter what angle the shaft makes with the bearing. A glance at Fig. 2, Sec. 7b, will best explain this. As will be seen, the bearing consists of an inner race with two grooves, two rows of balls, a retainer and a spherically ground outer race. The inner surface of the outer race is ground in the surface of a sphere, whose centre is on the axis of the shaft (see Fig. 2, Sec. 7b, Fig. 3, Sec. 7b, Fig. 4, Sec. 7b, Fig. 5, Sec. 7b).

This leaves the inner race, balls and retainer free to pivot into any position with respect to the outer race, and also permits free rotation of the bearing in any position.

The advantages of such a construction are obvious. Not only is pinching and binding impossible, but springing and deflection of the shaft,

* See index on rolling friction; there is some flattening effect.

FIG. 3. SEC. 7b.—S. K. F. thrust ball bearing, with aligning washer.

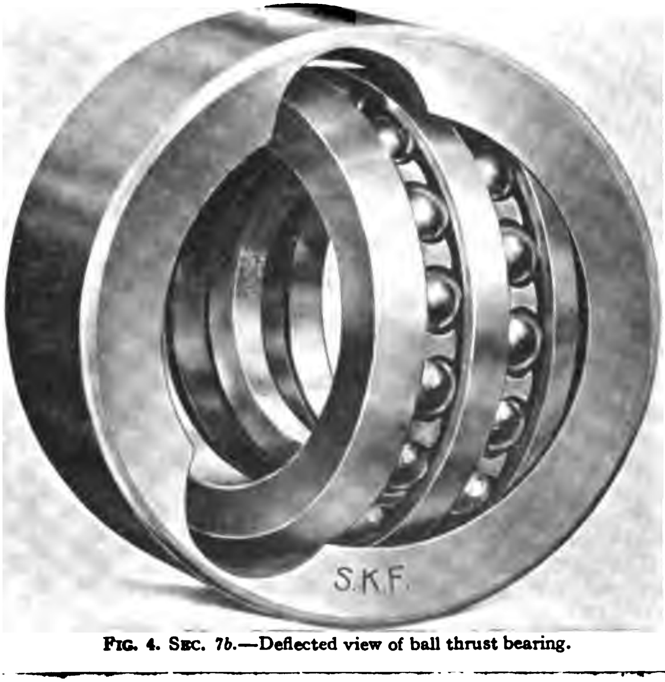


FIG. 4. SEC. 7b.—Deflected view of ball thrust bearing.

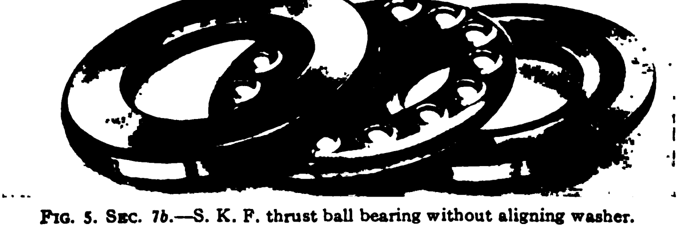


FIG. 5. SEC. 7b.—S. K. F. thrust ball bearing without aligning washer.

as well as misalignment and errors in machining, will not in any way interfere with absolute freedom of rotation.

The self-aligning ball bearing is an exceedingly accurate mechanism. Each bearing is accurate to the ten-thousandth part of an inch, and, with the proper care, this accuracy is lasting.

The first requisite is that the proper bearing be selected to meet existing conditions of load, speed, overload, temperature and other contributing factors.

The second requisite is proper care of the bearings. Housings of iron should be designed to encase the bearings, and felt seals, which are used to protect the bearing from foreign matter and prevent the escape of lubricant. For use on line shafting proper, casings are provided with the bearings. For all other purposes it is, of course, necessary to design and manufacture housings that are especially adapted to the case in hand.

NOTES ON BALL BEARINGS.—("Ideal Power," Chicago Pneumatic Tool Company publication): "With reference to ball bearings, exhaustive tests of the many types and sizes of bearings have developed practical working data for use by the engineer. It was found that within the limit of numbers of balls and rollers in an ordinary journal, one-fifth might be considered as practically sustaining the entire load, though naturally not equally. For roller and ball bearings, angular velocity, or turning speed, has comparatively little influence within quite wide limits for roller bearings, wider for ball bearings. * * * It is well known that the friction of plain bearings at rest is comparatively very high. This was found to be true for rollers, though not to the same degree. For ball bearings, the friction of rest and motion was found equally low. This is of great importance in all machines that must be started and stopped frequently. * * * One of the findings that completely reversed previously established theory was the relatively high carrying capacities and low friction of the ball bearing as compared with the roller bearing. Prior to this differences in the two were predicated upon the theory of a 'line and a point contact,' assuming that there was a pure rolling action in both cases. But 'true rolling' is a theoretical possibility merely, requiring for its realization absolutely true shapes, initially and inelastic materials that will not change shape under load. To produce a series of rollers that are truly cylinders and alike as to diameter, also a cylindrical shaft for them to roll on, and a truly cylindrical box to roll in, within the requisite small limits of error, is difficult and commercially not apparently realizable. * * * More serious still is the fact that under heavy loads such accuracy as may be had is largely defeated by the deflection of the machine framing. This causes the rollers to skew more or less; and it follows that the theoretical, long-line contact of the roller does not exist in fact, but is limited to a small fraction of the roll length. The test showed increasing power consumption as rolls were lengthened, and decreasing as rolls were shortened. * * * Specialists can deliver balls that are true spheres to within one ten-thousandths of an inch at relatively small cost. * * * After endless numbers of experiments to provide for proper load distribution * * * the simple plan of using a single row of balls and that of suitable proportion of the load was adopted. This resulted in a journal having no appreciable length, and accordingly free from trouble caused by deflection. The problem was then to proportion the diameter and the number of balls to

the load to be carried. As the number of balls in a circle was necessarily limited, and as the journal diameter could not be definitely increased, it became important to develop the carrying capacity, as affected by the shape of the ball tracks and the nature of the materials. * * * It was found that frictional resistance was least for balls rolling between straight line sections or perfectly flat surfaces giving two points of contact. Increasing the points of contact to three or four produced higher frictional resistance without materially affecting carrying capacity. Curving the race resulted in an important increase in carrying capacity, with a barely measurable increase in friction. This greater carrying capacity is accounted for by the fact that in a roller bearing, in the absence of grit, there is no wear as in a sliding bearing, but a destruction by crushing of the surface in actual contact. This point in a race when overloaded is flaked out. If in a ball bearing the race is curved, the stressed particle cannot be flaked or pushed out, being confined and supported by the wedges of material on either side. The resistance to crushing is thus greatly increased by curving the race."

Many ball bearings are equipped with felt packing to keep the lubricant in the bearing and to keep the dirt out. Felt washers frequently cause trouble by losing their contact with the shaft, due to felt hardening, and they then wear away quickly.

A good plan is to encircle the felt washer with a wire spring ring, so that this pressure will keep the felt in contact with the shaft.

BALL-BEARING MANUFACTURE.—Ball bearings must be made of the proper quality of steel, and great care must be taken in their manufacture to produce the surfaces of the balls and the races so that they will be free from surface defects. The steel must be heat treated, to give the desired physical properties. The bearings must be carefully mounted and so designed as to exclude all dirt and grit from the bearings. When wear once starts in a ball bearing, the bearing will deteriorate very rapidly. The races and balls should be accurate to 0.0001 of an inch, so that there will be no tendency to concentrate the load on a few balls in the bearing, as in that case the ball so overloaded would quickly start to wear.

BALL BEARING DATA.—As a matter of interest in illustrating the waste of power in various line-shafting bearings, the following table is given, based on data secured from a paper of the American Society of M. E., 1914:

Hanger type	100 feet per minute		300 feet per minute	
	77° Temp.	100° Temp.	77° Temp.	100° Temp.
Ball bearing hanger	1.0	1.0	1.0	1.0
Roller bearing hanger	2.2	2.5	2.7	3.0
Babbitt bearing hanger	3.0	3.6	4.5	4.0

NOTE. The relative numbers are based in each case on the average power consumed for three loads: 710, 1210 and 1710 pounds for the balls; 740, 1240 and 1740 pounds for the rollers; 730, 1230 and 1730 pounds for the babbitt bearings.

BALL-BEARING LUBRICATION

Proper lubrication of ball bearings is a feature not to be neglected. It is true that ball bearings do not require constant attention or lubricant in such large quantities as plain bearings do. But this should not be construed to mean that ball bearings need no attention.

The lubricant used in ball bearings, whether grease or oil, must be of the highest grade obtainable. It must be a lubricant that is strictly neutral containing neither free acid nor alkali originally nor through deterioration. Graphite should never be used nor should vegetable or animal oils be employed.

At low speeds and for heavy loads ball bearings should be packed with the best grade of petroleum jelly or mineral grease. For high speeds the best grade of mineral oil should be used. It is by far the best to use the type of lubricant recommended by the ball-bearing manufacturers. Each specific application needs some study to determine what lubricant is to be employed, and when a recommendation is made it should be followed. It is impossible to state in a general way when grease and when oil should be used, as such a statement would necessarily be too broad.

A little watching, when new machines are put into service, will soon indicate how often new lubricant must be applied. Naturally this varies with the different applications. In some cases new lubricant must be added every two weeks, in others every six months is ample. There have been cases of continuous service over a period of two years on the original lubricant, but such scant attention is not advised.

Even if ball bearings will run for such length of time without fresh lubricant, it is advisable to clean the bearings once every six months. Flush out all old lubricant with gasoline and then refill with fresh lubricant. See that felt seals are soft and unworn. If hardened or worn to any extent they should be replaced. A little periodic attention of this nature insures perfect operation.

Under no circumstances should a ball bearing run dry. Ball bearings have balls and races with highly polished surfaces, which would be destroyed by such treatment. The close accuracy and wearing qualities of the bearing would be lost and ruin would be inevitable.

There is a list of instructions provided by ball-bearing makers. This list covers the handling and care of ball bearings both before and after installation. A careful observance of the points it sets forth will assure satisfactory service from these bearings.

Some bearing manufacturers insist on specifications calling for a light-bodied grease, with not higher than .02 per cent. of free acid or .04 per cent. of free alkali. These practically exclude a commercial lubricant, except a straight mineral product, such as petrolatum, cut back with a neutral oil, to give the consistency of No. 2 or No. 2 1/2 cup grease.*

There is a slight rolling action between the balls and the separator, and a lubricant must be interposed to reduce the consequent friction.

The lubricant used in ball bearings must be neither acid nor alkali, but must be neutral. A simple test for ball-bearing lubricants may be

* See also page 402.

made by coating a highly polished steel surface with the oil or grease under observation. After exposing it to the heat of the sun for several days, any corrosive tendencies will be evident upon the polished surface of the plate. Oil containing any compounding of animal or vegetable oils should never be used in ball bearings, as it will produce gumming and become rancid. The best lubricant for these bearings is a strictly mineral oil. For high-speed bearings, a light machine oil should be used, and for slower moving bearings use a heavy viscous oil or a straight petroleum grease. Petroleum greases have poor consistency characteristics under increasing temperatures, however, and quickly run out of the bearings. Well-designed bearings are provided with suitable retainers for the purpose of holding the lubricant in the bearing and preventing its creeping out along the shaft. Engine grease or cup grease should not be used in ball bearings unless it is carefully tested for the presence of free alkali and free acid, which will pit and corrode the bearing if present. Greases should not be used in ball bearings running at over 1200 R. P. M. Graphite is not satisfactory for use in ball bearings, because of its tendency to pack. Oil is the best all-around lubricant for these bearings.

EFFECTS OF RUST.—Rust is destructive to a ball bearing. It can be recognized, even in a bearing that has been cleaned free from red rust, by the presence of pronounced pits, not only on the race surfaces, but on the other parts of the bearings. "Rust pits" are generally all over the bearings, while "overload pits" are confined to the ball tracks and to the balls themselves.

"Pitting," due to the presence of free acid or alkali in the lubricant used, may be easily distinguished from that due to rust or overload, since the pits show up as clearly defined etchings. Overloaded ball bearings do not wear, but the polished surfaces of the races and balls will be destroyed. This is indicated by small "pin holes" and "chipping."

Dust and dirt quickly damage the highly polished surfaces of the balls and races. The drain holes and oil holes of the housing must be kept closed by a cap to avoid leakage of the lubricant and the entrance of dirt.

BALL BEARING LUBRICATING DATA.—In the operation of ball bearings, there are certain characteristic differences existing between their lubrication as compared with the important points of lubrication of plain bearings. In designing a plain sleeve bearing, it is important to allow for the formation and maintenance of a continuous oil film. The oil for the maintenance of this film should then be selected so as to provide a film of maximum strength and having a minimum amount of internal friction. In the case of a ball bearing, however, the following characteristic points should be noted:

1. At light loads and moderate speeds, the coefficient of friction of an unlubricated ball bearing is lower than that of a lubricated ball bearing. This characteristic of a ball bearing is not generally known, and should not be used as a basis for advocating the operation of ball bearings without lubrication. As previously stated, the use of a lubricant in ball bearings is necessary in order to protect the highly polished surfaces of the balls and raceways and to reduce to a minimum the slight friction which occurs in operation between the balls and ball container. However, this small amount of friction which occurs between the balls and retainer can also be reduced by careful design. The important requirement of a ball bearing lubricant is its chemical neutrality. In this connection, a ball-bearing lubricant should not contain over 0.10 per cent. free acid or alkali. There are very few commercial lubricants which will meet this last requirement. In general, the most satisfactory lubricant for a ball bearing is a highly refined mineral oil. This oil should not contain over a minimum amount of free acid, alkali or sulpho-compound. Greases should only be used for lubrication where operating conditions require viscosities greater than can be obtained with a mineral oil. In operating a ball bearing at high speed, provision should be made to supply the oil for lubrication by means of a pressure system, as it is not recommended to run the bearings submerged in a lubricant. Where the pressure system is not available, sight-feed oil cups, feeding a few drops of oil per minute, are recommended. At moderate speeds, a heavy oil (300–500 sec. Vis. Say. at 100° Fahr.) will usually produce better lubricating results than a light oil running 100–200 sec. Vis. Say. at 100, and in this connection, in cases where a heavy oil has been substituted for a light oil, the operating temperatures show a decrease, which may be explained by assuming that when the bearing is operating at its actual running speed, the inertia of the heavy oil offers less opposition to the rotation of the ball, and there is a lower tendency for churning and frothing, with its resultant air pockets, which air pockets act as heat insulators, tending to prevent the transmission of the frictional heat to the outer bearing casing, from which it may be radiated. Lubricants of the semi-fluid type may be successfully used in place of a heavy oil, providing they will meet the requirements as to free acid and free alkali.

2. The coefficient of friction for a well-designed ball bearing is to all practical purposes constant throughout wide ranges of loads and speeds.

In this respect, they differ from sliding-contact bearings, in that with a sliding-contact bearing, which requires an oil film to prevent metallic contact and high friction, a certain speed must be reached before a satisfactory oil film will be formed. (The reader is referred to the index, showing the action of an oil film in a sliding-contact bearing.)

3. An oil film is only possible between the balls and the races of a ball bearing at very high speed, when slippage may occur, and at other times, for average conditions, there is metal-to-metal contact between the balls and the races, and this is particularly demonstrated by characteristic curves plotted between the revolutions of the shaft and coefficient of friction for a ball bearing and a plain babbitt bearing.

BALL-BEARING LUBRICATION WITH GREASES.—Lubricating greases, as previously stated, for use in ball bearing, should not show over 0.10 per cent. of free acid, calculated as oleic acid, or over 0.10 per cent. of free alkali, calculated as *NaOH* (Sodium Hydroxide). They should not contain more than 0.5 per cent. of free lime, calculated as calcium oxide, nor more than 1 per cent. of uncombined saponified fatty oil, expressed in the analysis as neutral unsaponifiable oil. The viscosity of the mineral oil used in the manufacture of these greases should be at least 200 sec. Say. at 100° Fahr., and the grease should be free from grit and other abrasive substances.

One method of determining acidity in a grease manufactured with lime soap is a modification of Marcusson's method, which involves the following operations: Ten grams of the grease weighed into an extraction flask and dissolved by shaking cold in 88° gasoline, avoiding beating or boiling, which may cause some of the free lime to combine with the free acid. The soap is then allowed to settle and a clear gasoline solution is poured on a filter without stirring the soap. The insoluble soap, lime, etc., are then treated again with gasoline, and allowed to settle clear and poured on filter paper. The filtered soapy residue is then washed several times with gasoline until all soluble matter is washed out. The filterings and washings are collected in Erlenmeyer flask of sufficient capacity and the gasoline slowly distilled off on an electric hot plate, care being taken not to carry the distillation down too far, as to avoid breaking up the oils. The residue is then washed into a stoppered bottle, with a small amount of gasoline, and 50 c.c., with 50 per cent. of neutral alcohol is added and titrated with standard N/100 sodium hydroxide solution, the mixture being thoroughly shaken as each drop of the solution is added. Phenolphthalein is used as an indicator. The acid content can be determined with this method to within 0.02 per cent. calculated as oleic acid.

The ball-bearing manufacturers have universally agreed that the limit of free acid in a grease must not be in excess of 0.10 per cent., calculated as oleic acid.

The reason for limiting the percentage of unsaponified fatty oil, referred to as neutral unsaponifiable oil in analyses, to not more than 0.10 per cent. is due to the fact that the unsaponified fatty oil has a tendency to become rancid and develop acidity in service, particularly where the operating conditions are subject to high temperatures.

The mineral oil which is used in the manufacture of a ball-bearing grease should meet the requirements of the mineral oils used for ball-bearing lubrication, as previously outlined, which imposes the specification that they shall not contain more than 0.10 per cent. of free acid. calculated as oleic acid; that they shall be free from free alkali and not show more than a trace of ash. They should have an open flash test of at least 300° Fahr., and should not show more than a slight darkening and no sediment when heated in a flask or beaker when heated up to their

flash-point and held at this temperature for 15 minutes. Oils which contain sulphuric acid compounds turn black and deposit carbon-like substances when subjected to this test, and are not suitable for ball-bearing use. (See index for heat tests.)

The presence of sulpho-compounds in a mineral oil may be definitely indicated by an emulsion test. (See index.)

The high polish necessary for the surfaces of ball bearings and races makes essential the specification pertaining to greases that they shall not contain any substances of an abrasive nature. (See index for other tests pertaining to grease.)

BALL-BEARING LUBRICATION AND GRAPHITE.—Since graphite is not a true lubricant, but tends only to fill in the hollows of plain bearing surfaces, in order to allow the true lubricant to efficiently function, it is not a satisfactory lubricant for ball bearings, inasmuch as the modern ball bearing is made with a high finish, so that there will be practically no unevenness on the surfaces. In this connection it may be stated that a perfectly finished ball should show no scratches or unevenness when magnified 100 diameters.

There is a difference also between the sliding action of a plain bearing and the rolling action of a ball bearing, which is particularly important with reference to graphite lubrication.

Graphite has a tendency to pack in the ball retainers and raceways, and ball bearings which have been lubricated with a graphited grease generally show a distinct wavy appearance in the ball paths.

Colloidal graphite contained in a grease, while showing an absence of the wavy ball paths and giving a burnished appearance to the raceway, is not satisfactory, however, due to the fact that the graphite packs hard in the ball retainer and is difficult to remove.

SECTION 7c

ROLLER BEARINGS

TYPES.—There are two general types of roller bearings; namely, those with hardened steel solid rollers and those with flexible, helical, hollow rollers.

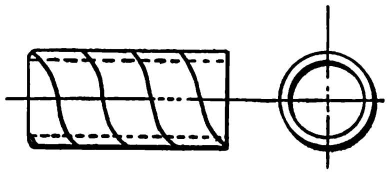


FIG. 1. SEC. 7c.—Flexible roller bearing.

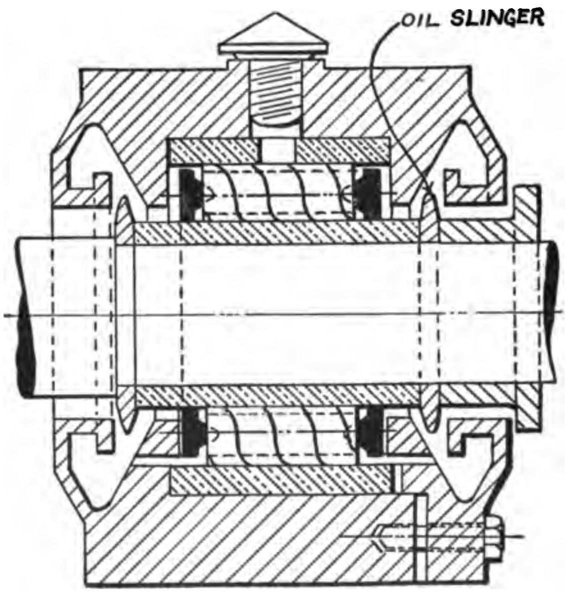


FIG. 2. SEC. 7c.—Roller bearing with flexible rollers.

ROLLER BEARINGS.—"Roller bearings" consist of a steel sleeve, which fits on the shaft and on which the rollers travel. The "yoke," or "cage," holds the rollers in place, and an outer shell surrounds the rollers and carries the load.

Journal roller bearings having solid rollers may be equipped with either cylindrical or conical rollers. Solid roller bearings found in automobiles usually have conical rollers, while those found in machinery usually are equipped with cylindrical rollers.

Journal bearings which are equipped with flexible, hollow rollers have cylindrical rollers only. These rollers are made by winding a flat

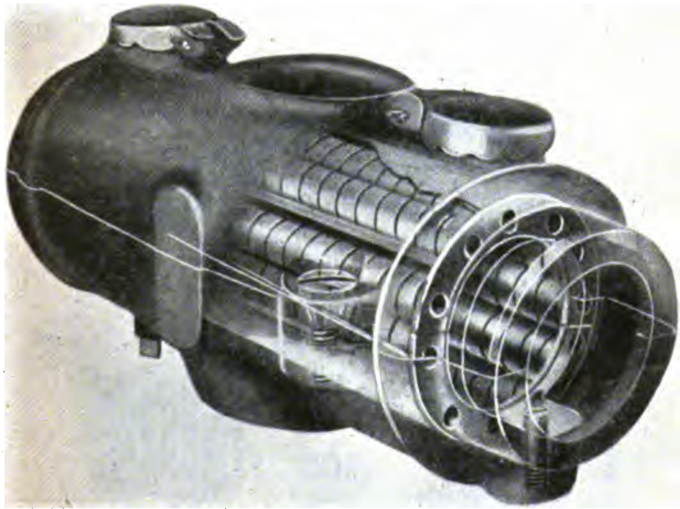


FIG. 3. SEC. 7c.—Hyatt line shaft, roller bearing.

strip of steel into a hollow coil, as shown in Fig. 1, Sec. 7c. Their chief advantages over the solid type of rollers are (*a*) their flexibility, which permits of a slight irregularity in the bearing alignment; (*b*) their capacity for carrying a supply of lubricant within their hollow interiors; and (*c*) the assistance given by the helical grooves in the distribution of the lubricant, by screwing it along over the roller surface.

Typical flexible roller bearings are shown in Fig. 2, Sec. 7c., and Fig. 3, Sec. 7c.

Typical solid roller bearings are shown in Fig. 4, Sec. 7c, and Fig. 5, Sec. 7c.

THE LUBRICATION OF ROLLER BEARINGS

A heavy-bodied oil or a semi-fluid grease should be used for the lubrication of roller bearings.

The helical cracks, on the surfaces of the rollers of the flexible type, give the best service with a medium-bodied oil, if the bearing is so designed that suitable provision has been made for the retention of the oil in the bearing.

The pressures on these bearings are usually about 450 pounds per square inch of developed bearing for a speed of about 50 R. P. M., which would be considered an extreme low speed and a maximum load.

FIG. 4. SEC. 7c.—Thrust roller bearing.

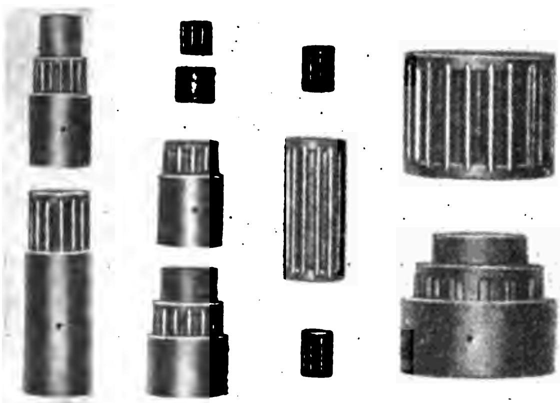


FIG. 5. SEC. 7c.—Solid roller journal bearing.

For heavy duty bearings running at 1000 R. P. M. the unit load may run as high as 800 pounds per square inch. The speed of these bearings rarely exceeds 3000 R. P. M.

A pure, semi-fluid grease makes an excellent lubricant for this type of bearing. The grease should be particularly free from gumming defects and should retain its body well when heated in the bearing.

SOLID ROLLER BEARINGS.—Solid rollers are sometimes used in heavy bearings of the high-speed thrust type, such as are found in large vertical turbines. The rollers used in this type of bearing are short and have large diameters, due to the fact that in their circular path their motion is a combination of a sliding-rolling motion.

The demands made upon the lubricant for this type of bearing are excessive. The contact lines of the cylindrical surfaces of the rollers give practically no bearing surfaces, and the wiping effect produced by their travel in a circular path, which tends to scrape the lubricant from the bearing plates, requires that the supply of oil be excessive, so that the wiped-off oil is immediately replaced by fresh oil. These bearings are, therefore, usually run in flooded lubrication, the oil being pumped through a hole in the lower bearing plate *B* (see Fig. 6, Sec. 7c) into the space below the inside edge of the rollers and separated from the shaft by an

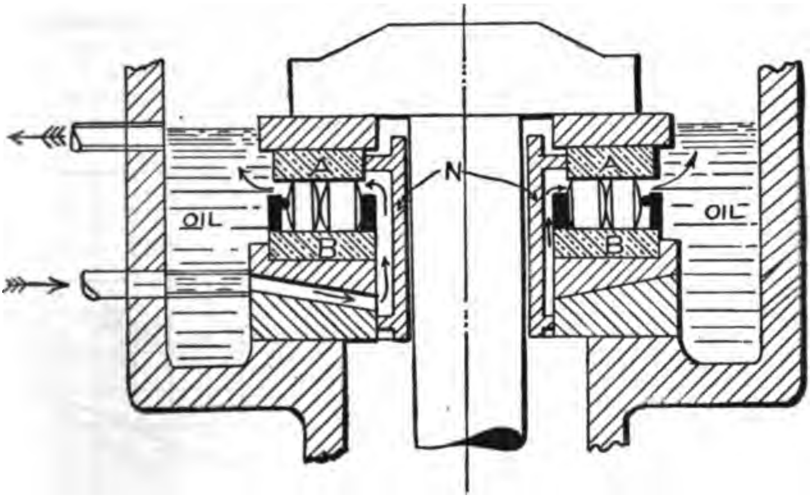


FIG. 6. SEC. 7c.—Vertical roller bearing.

oil guard, as shown at *N* in the figure. The oil rises, due to the suction produced by the centrifugal action of rollers and to the force of the feed, which may be produced by a pump or by gravity. It is drawn into the spaces between the rollers and is thrown out, from the outside ring of rollers, by their centrifugal action, combined with their wiping action. The oil is allowed to overflow above the upper bearing plate *A*, to a filter and settling tank, from which it is again drawn for circulation.

The total loads on these bearings are often as high as 175 tons, and the speeds may be as high as 95 R. P. M. The oil used should have a viscosity of about 200 to 220 Saybolt (P. B.) and 300 to 350 Saybolt (A. B.).

SECTION 7d

LINE-SHAFT BEARINGS

COMPARATIVE TESTS OF RING-OILED BABBITT ROLLER (HOLLOW HELICAL) AND BALL-BEARING, LINE-SHAFT BEARINGS.—Mr. Carl C. Thomas read a paper before the annual meeting of the American Society of Mechanical Engineers in 1913 covering a series of tests made on line-shaft bearings. Mr. W. G. Moyer, Mr. William Black, Prof. E. R. Maurer and Mr. L. E. A. Kelso took part in

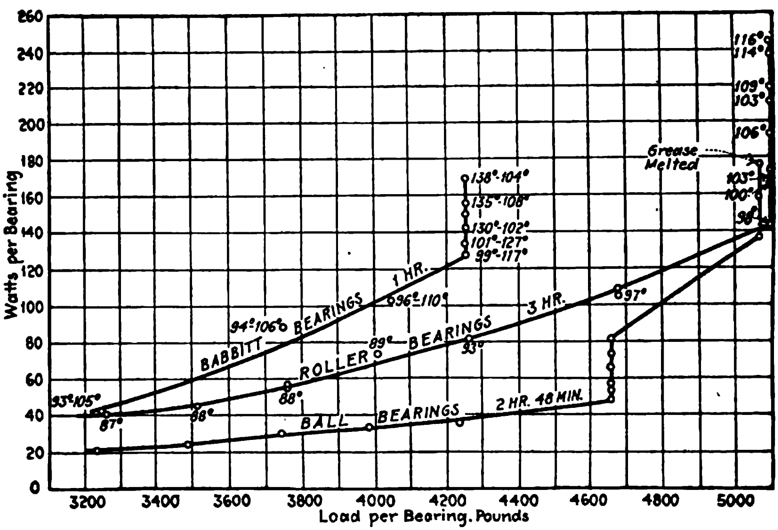


FIG. 1. SEC. 7d.—Breakdown tests, 200 R. P. M., 128 ft. per minute.

making these tests at the University of Wisconsin. Twenty bearings of each type were used in the tests in order that representative tests might be obtained. The shafts were cold-rolled steel, 2 7/16 inches in diameter. Each section of shafting was 5 feet 2 inches in length. The three kinds of bearings used in the tests were: Hess-Bright ball bearings, manufactured by the Hess-Bright Ball Bearing Company; ring-oiled bearings, manufactured by the Dodge Manufacturing Company, lined with babbitt metal of the following composition: Lead, 86.1 per cent.; antimony, 11.9 per cent., and tin, 2 per cent.; Hyatt roller bearings. The babbitt bearings were 9 21/32 inches long, giving a projected area of 22.36 square inches.

The following table is given in the paper for converting total loads, as referred to in the tests, into unit loads:

730	1230	1730	2230 pounds per bearing.
33	55	78	100 pounds per sq. in.

Each ring-oiled bearing contained two rings.

Each roller bearing contained six right-hand and six left-hand rollers, 0.780 inch in diameter; six were 9 9/16 inches and six were 9 3/16 inches long.

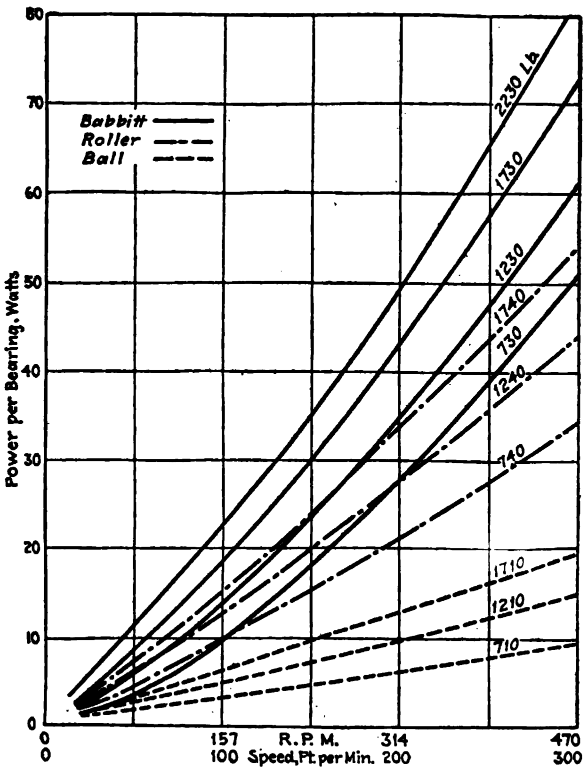


FIG. 2. SEC. 7d.—Comparison of powers consumed by friction in the Babbitt roller and ball bearings, at loads per bearing as indicated and various speeds; temperature of bearing, 100° Fahr.

Each ball bearing contained a single set of balls 9/16 inch in diameter. The diameter of the race, through the ball groove, was 3.4729 inches.

Two lubricants were used in all tests, as follows: For babbitt and roller bearings an oil having the following tests: 440° Fahr. flash, 260 Vis.

Say. at 100° Fahr., 24.5 B. Gravity. For the ball bearings a No. 2 cup grease was used.

Some of the interesting results obtained from these tests and reported in the paper are as follows: A test was run, starting at about 3200 pounds per bearing, with a shaft speed of 200 R. P. M. (this speed having been

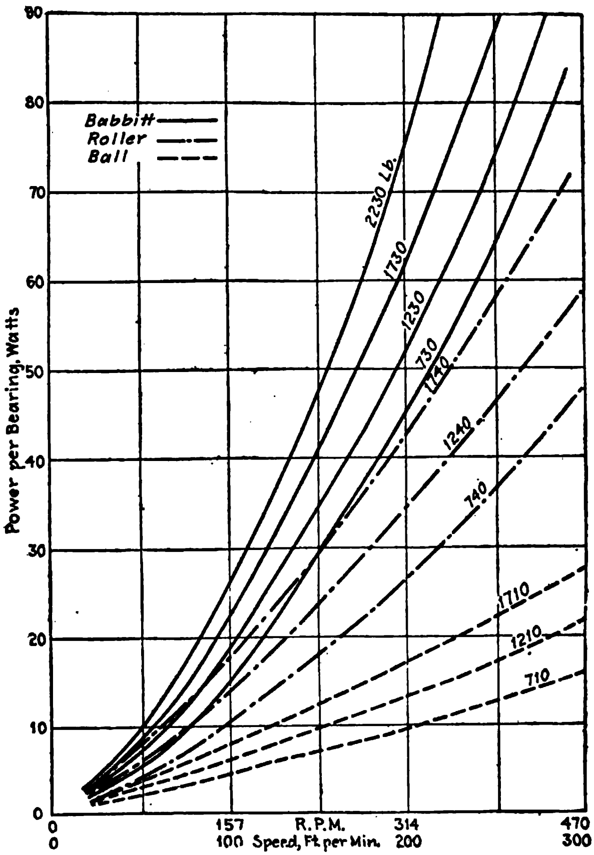


FIG. 3. SEC. 7d.—Comparison of powers consumed by friction in the Babbitt, roller and ball bearings, at loads per bearing as indicated and various speeds; temperature of bearing, 77° Fahr.

chosen by the experimenters because it represents average line-shaft speed as met with in practice), to observe the behavior of the three types of bearings under very heavy loads and to obtain a so-called "Break-down Test."

It was found that failure for the babbitt bearings occurred at about 4250 pounds. In the case of the ball bearings, the "break-down point"

was 4650 pounds per bearing, and in the roller bearings 5100 pounds per bearing. The bearings did not fail structurally, as the experimenters cut off the power soon after trouble was evidenced, the failure being simply that of the lubricant. The "break-down point," resulting in an immediate increase in power, required to drive the shaft at the original speed. The curve shown in Fig. 1, Sec. 7d, taken from this paper graphically illus-

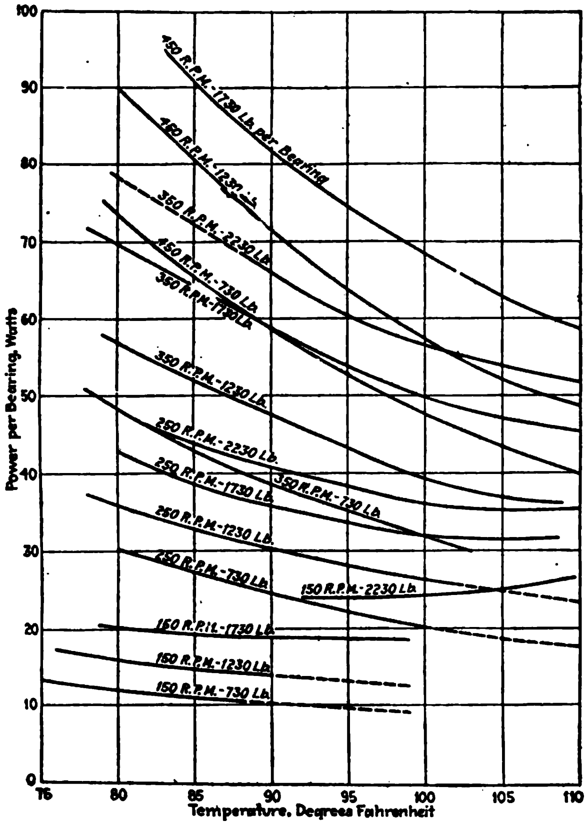


Fig. 4. Sec. 7d.—Babbitt bearings. Power temperature curves for various speeds and loads per bearing.

trates the test results. It is particularly interesting to note the action of the ball bearings at "break-down." The authors state that the grease in these bearings disintegrated and melted, running out of the bearing at this point. This was accompanied by an immediate increase in power.

The two curves shown in Fig. 2, Sec. 7d, and Fig. 3, Sec. 7d, show some striking results obtained by these tests from a comparative standpoint of speed and power at two temperatures.

Another set of curves from this paper are shown in Fig. 4, Sec. 7d, Fig. 5, Sec. 7d, and Fig. 6, Sec. 7d, illustrating the effect of temperature upon the lubricant and the power to drive the bearings.

Mr. E. H. Ahara in a written discussion of this paper has also brought out some very interesting data. He describes some tests conducted by himself at the plant of the Dodge Manufacturing Company, Misawaka, Ind. In the apparatus he describes as having used in his test the pressure

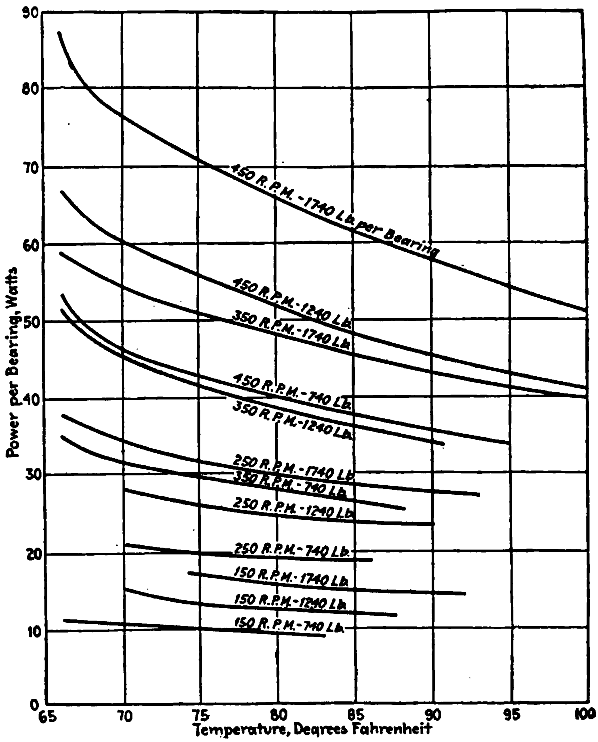


FIG. 5. SEC. 7d.—Roller bearings. Power temperature curves for various speeds and loads per bearing.

was "downward" on the test bearing, the bearing being placed between two bearings, which took the upward pressure, and thus having but half of the load of the test bearing. The test was undertaken to determine the limit of power and speed at which these same babbitted bearings as spoken of in the paper of Messrs. Thomas, Maurer and Kelso could be run before the film of oil would no longer stay between the babbitt and shaft. A speed of 2200 R. P. M. gave a peripheral travel of the shaft of 1404 feet per minute. The pressure was gradually increased until the practical limit of the oil was reached and the temperature measured by a

practical method described in the above-mentioned paper. * * * The test at 2200 R. P. M. and a definite pressure was continued until there was no further rise in temperature, when a higher pressure was taken. Different grades of babbitt were used by Mr. Ahara. He gives data as follows: "The same kind of oil was used as is described in the paper previously referred to. Pure lead was tested up to 100 pounds per square inch of projected area, with a temperature of 292° Fahr.; pure tin to 124 pounds, with a temperature of 276° Fahr.; genuine babbitt, with a compo-

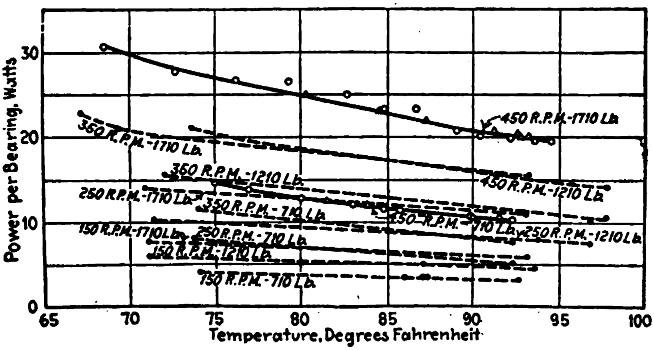


FIG. 6. SEC. 7d.—Ball bearings. Power temperature curves for various speeds and loads per bearing.

sition of copper 4 parts, tin 89 parts, antimony 7 parts, reaching a pressure of 124 pounds with a temperature of 282° Fahr., and a composition of copper 2 parts, tin 40 parts, antimony 14 parts and lead 44 parts, reaching a pressure of 144 pounds, with a temperature of 290° Fahr. A composition of tin 5 parts, antimony 17 parts and lead 78 parts reached 83 pounds with a temperature 298° Fahr., and a composition of antimony 15 parts and lead 85 parts reached only 62 pounds with a temperature of 314° Fahr. At low pressure no appreciable difference was noticed in the heating values, but in the high pressures the tin-based babbitts, with small copper contents, were found much superior."

SECTION 7e
BEARING LUBRICATION

EQUIPMENT AND METHODS

SIGHT-FEED OIL CUPS.—Sight-feed oil cups are usually equipped with needle valves and may be obtained in capacities ranging fromm 5/8 ounce to one pint.

Fig. 1, Sec. 7e, illustrates the typical form of oil cup, of the quick-stop, glass body type. The valve stem is raised or lowered to regulate

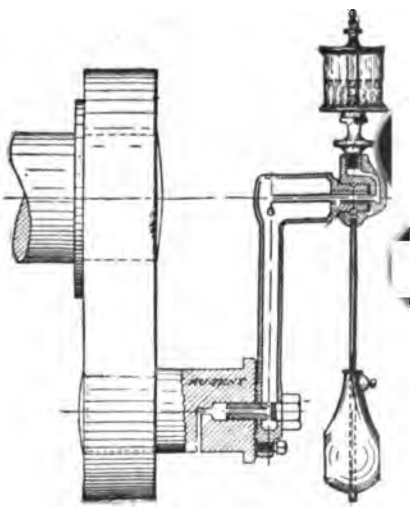
FIG. 1. SEC. 7e.—Sight-feed oil cup.

the feed of oil by means of a milled nut. When the lever is raised to the perpendicular position the cup is feeding, and when down in a horizontal position the feed is shut off. By turning the lever in a 45° position the bearing may be flooded with oil.

This type of oil cup is used for individual bearing and slide lubrication.

FIG. 2. SEC. 7e.—Phenix swivel sight-feed oiler. (Circulating System.)

A



B

FIG. 3. SEC. 7e.—Nugent's anti-stand crank-pin oiler. A, outside view. B, sectional view.

SIGHT-FEED OILERS FOR CIRCULATING SYSTEMS.—Fig. 2, Sec. 7e, shows the construction of the Phenix Swivel Sight-feed Oiler, made by the Richardson-Phenix Company, of Milwaukee, Wis.

These sight feeds are used at the various points of lubrication to regulate the flow of oil supplied by a continuous-flow system.

An adjustable needle valve, with a stuffing gland and milled nut,

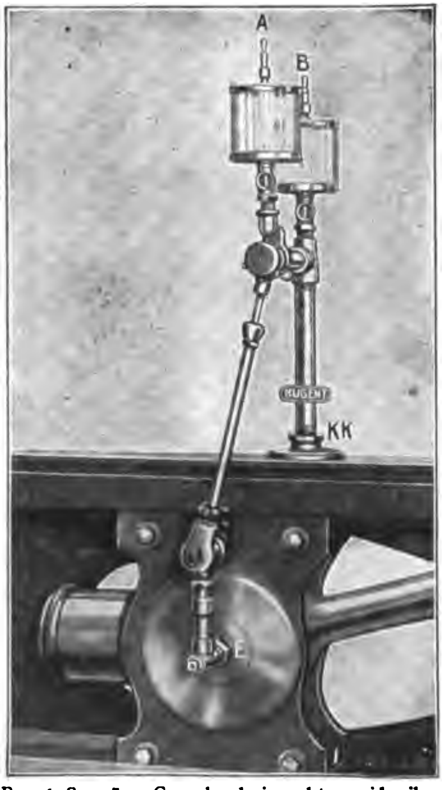


Fig. 4. Sec. 7e.—Cross-head pin and top guide oiler.

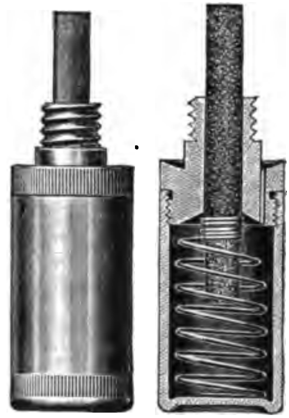


Fig. 5. Sec. 7e.—Type of wick feed oil cup which is used in electric fans.

Fig. 6. Sec. 7e.—Another type of oil cup with a wick feed.

regulates the flow, which is indicated by the sight-feed glass. By the use of the oiler the feed at any point may be regulated.

CRANK-PIN CENTRE OILERS.—Fig. 3, Sec. 7e, shows the Nugent Patented Anti-stand, Crank-pin Oiler, manufactured by Wm. W. Nugent & Co., of Chicago.

This device provides a very efficient method of applying oil to the crank pin and is positive in its action. The oil cup may be removed and a

suitable open cup substituted, so that the crank pin may be supplied with oil from a continuous oiling system by feeding the oil from above.

As seen from the cut, the oil cup remains stationary and in an upright position during the revolutions of the crank, being located upon the same axis of rotation as the shaft.

Fig. 4, Sec. 7e, shows a well-known type of Cross-head Pin Oiler and Top Guide Slide.

This type of device does away with the unsatisfactory "wiper cup," and insures a uniform supply of oil direct to the pin.

This cup type of telescope oiler, or one connected to a circulating system, is of particular value for use on vertical engines, such as marine engines, for the lubrication of the eccentrics.

Fig. 7. Sec. 7e.—Oil gauge for self-oiling journal.

Usually the eccentrics of these engines are equipped with an oil boat, into which the oil is dropped from a stationary source. A large waste of oil occurs, due to the suction or air draft produced by the moving cranks, which draws the oil out of its course.

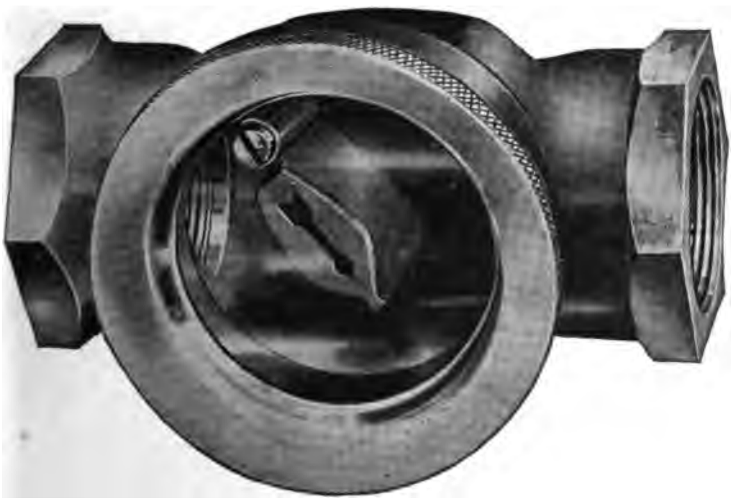


Fig. 8. Sec. 7e.—Sight flow indicator.

These oilers may be adapted for use on any reciprocating bearing, such as cross-head pins, double-disc crank pins and eccentrics of steam engines.

Fig. 5, Sec. 7e, shows a type of Wick Feed Oil Cup, which is used on electric fans, small motors, small dynamos and other types of high-speed

machinery, where it is desired to feed the oil steadily to the under side of the shaft. The amount of oil feed is controlled by the degree of wick pressure against the shaft.

Fig. 6, Sec. 7e, shows another type of oil cup with a wick feed.

OIL GAUGES.—Fig. 7, Sec. 7e, shows an oil gauge for dynamos and other machinery, having self-oiling bearings. This construction provides a method of indicating the level of the oil in the bearing reservoir and also a method for draining the oil off when desired.

SIGHT FLOW INDICATOR.—Fig. 8, Sec. 7e, shows a device called a sight flow indicator. This device is designed for use in the main lines of oiling systems to indicate whether or not the liquid is flowing in the line. It can be used advantageously in water lines of oil insulated transformers and in any place where there is a network of pipes carrying liquid and it is important to know that the flow is not interrupted. The indicator shown in the figure is made by the Richardson-Phenix Company.

The indicator may be constructed to indicate electrically.

BEARING LUBRICATION: SYSTEMS AND METHODS

METHODS OF FEEDING LUBRICATING OIL TO BEARINGS. —Bearings may be lubricated with oil by any one of or by a combination of the following-named methods:

1. Hand feed (cup feed).
2. Ring feed (self-oiling bearing).
3. Gravity feed (flooded lubrication).
4. Forced feed (circulating system).
5. Splash feed.
6. Special methods.
7. Wick feed.
8. Individual engine systems (self-contained).
   (*a*) Splash.
   (*b*) Bath.
   (*c*) Pressure.
   (*d*) Gravity.

METHODS OF FEEDING GREASE TO BEARINGS.—Grease is usually fed to bearings by one of the following methods:

1. Hand-feed grease cups.
2. Gravity or vibration-feed cups.
3. Compression grease cups (spring or air).
4. By exposing the journal to a block of the grease and allowing the frictional heat of the bearing to melt the grease and cause it to flow.
5. Compression feed cups, with automatic feed-control valves.
6. Screw-feed cups, marine type.

(1) HAND FEED

HAND OILING.—Hand oiling is effected by hand oil cans direct to the bearing, or by hand-filling independent oil cups, arranged to feed oil to each desired point of lubrication.

Oil cups are equipped with "sights" to note the rate of oil feed. These cups are equipped with small valves by which the rate of oil feed may be adjusted. They are usually tapped into the bearing cap of the bearing, the oil being fed onto the top of the journal and distributed over the bearing surfaces by the rotative action of the journal, with the assistance of the oil grooves.

With hand oiling there is a large waste of oil, because of the difficulty in regulating the flow of oil to just the proper amount required by each bearing. After passing through a hand-oiled bearing, the oil can be partially recovered only by means of drip pans, and there is consequently a considerable loss, even under the best operating conditions. Grit and dirt often cause considerable trouble when hand oiling is used, and the close attention necessary to maintain any sort of efficiency from a lubricating standpoint makes hand oiling dependent entirely upon the personal efficiency of the operator.

(2) RING OIL FEED

RING FEED.—Ring- or chain-fed lubrication consists in hanging a ring or chain on the journal, so that when it rotates the rings will turn with it. These rings dip into a reservoir underneath the bearing and carry the oil which adheres to them up to the upper surface of the journal.

A typical "ring bearing" is shown in Fig. 9, Sec. 7e.

OILING RINGS.—The rings used for ring feed must be smooth and free from any sharp edges that would cause interference with their free movements. The bearing must be so adjusted that the rings do not vibrate or jump.

The reservoir should be large enough to permit the oil returning from the bearing to have sufficient time to cool before it is again drawn up to the journal surface.

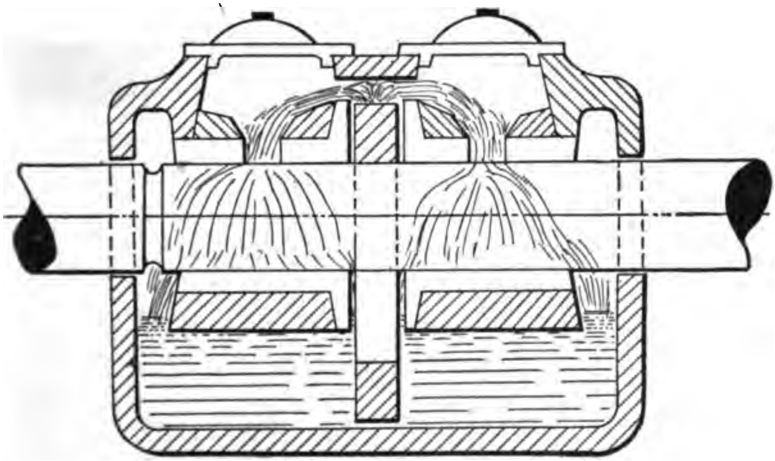


FIG. 9. SEC. 7e.—Bearing equipped with ring-fed lubrication.

There have been cases where hot running, ring-oiled bearings have been made to run cool by increasing the amount of oil held in the reservoir so that there would be a better cooling effect.

Fig. 10, Sec. 7e, and Fig. 11, Sec. 7e, show a Foster shaft hanger and ring oiling box. The boxes which carry the shaft are designed to provide a cavity around the bearing which contains the oil or other lubricant into which the rings dip. Two rings are carried in each box. This type of hanger will be found as part as many counter shafts made by the Foster Machine Company. These counter shafts have the loose pulley equipped with a Hyatt roller bearing. Counter shafts are usually located above, and, as a rule, do not receive as careful attention as they should. For the lubrication of this equipment, including the Hyatt roller bearing, a semi-fluid grease of three-quarter consistency is recommended.

FIG. 10. SEC. 7e.—Foster shaft hanger and box.

FIG. 11. SEC. 7e.—Box of Foster shaft hanger, showing rings.

FIG. 12. SEC. 7e.—Channel oiling ring.

CHANNEL OILING RING.—The channel oiling ring is designed to furnish positive lubrication without the use of a pump. The oil is taken from the oil pocket or reservoir by the rapidly revolving channel-shaped ring and is held within the ring by centrifugal force until it is diverted to the bearing by means of a scoop. It is expected to produce a positive pressure, which actually forces the oil to the bottom of the bearing. It is found in use in the Sturtevant turbine for main bearing lubrication. (See Fig. 12, Sec. 7e.)

(3) GRAVITY OIL FEED

GRAVITY FEED.—A gravity feed system consists of an oil reservoir or tank, which is placed at a higher point than any of the bearings to be fed. From this tank a main supply pipe is run to the base of the engine and the various feed pipes are tapped into it to carry oil to the different points of lubrication. The rate of feed at each bearing is regulated by a sight feed and needle valve, so that the various points of lubrication may receive individual adjustment.

Gravity feed systems are usually of the continuous, circulating feed type. In this type the oil running from the bearings is allowed to drain into a drip pan and is then drained to a settling tank. The dirty oil is then passed through a filter and again raised up to the gravity tank by

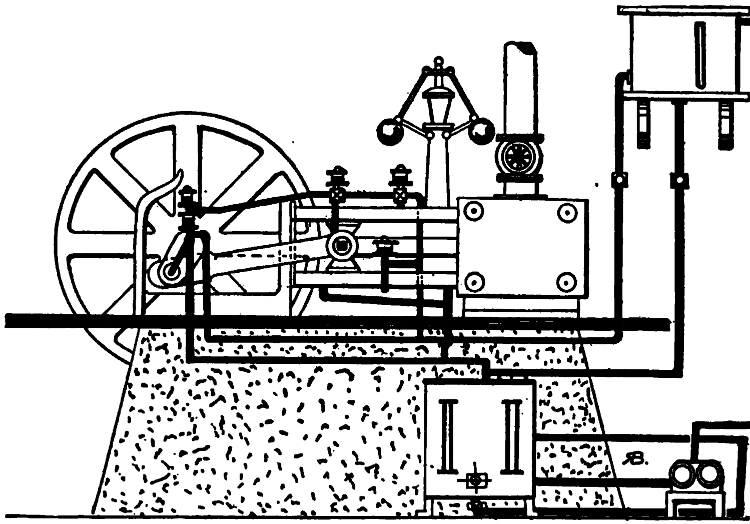


FIG. 13. SEC. 7e.—A typical continuous gravity oiling system.

means of a small pump, which is usually driven by some oscillating part of the machinery. From the gravity tank it is again put into circulation. A typical continuous circulating, gravity oiling system is shown in outline in Fig. 13, Sec. 7e.

The chief advantage of the above-described oiling system is the copious supply of oil which it permits supplying to all the points of lubrication.

GRAVITY OILING SYSTEM DIAGRAMS.—Fig. 14, Sec. 7e, and Fig. 15, Sec. 7e, show the course of oil flow and general arrangement of a filtering and circulating oiling system. The figures are self-explanatory, and are shown through permission of S. F. Bowser & Co.

OVERFLOW.—There should always be an overflow pipe from the reservoir or gravity tank, so that in case the feeds become clogged or

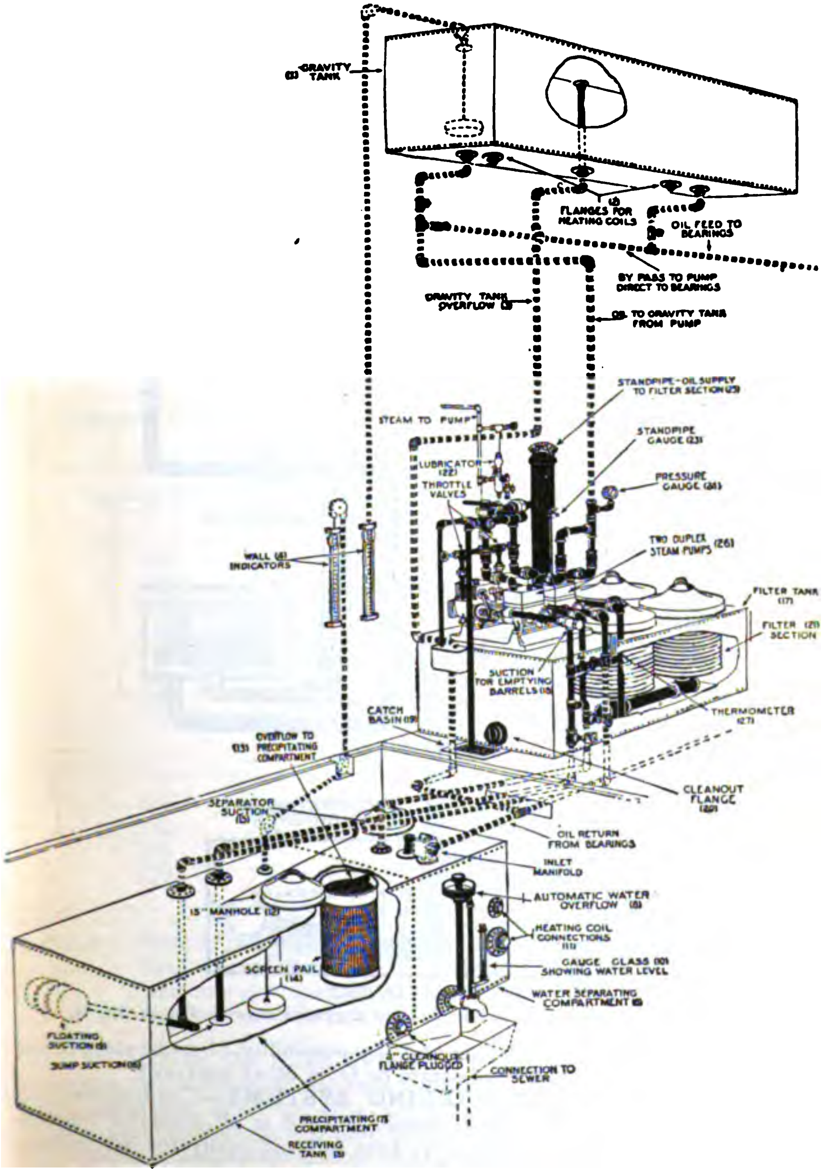


Fig. 14. Sec. 7e.—Large filtering and circulating system.

reduced the excess of oil will be returned to the filter. A circulating system does away to a more or less extent with the personal factor as an element of lubrication.

OIL FOR CIRCULATING SYSTEMS.—The oil for the continuous feed oiling system should be strictly a neutral, filtered oil. Oils with poor emulsion tests should be avoided, because of the possibility of emulsifica-

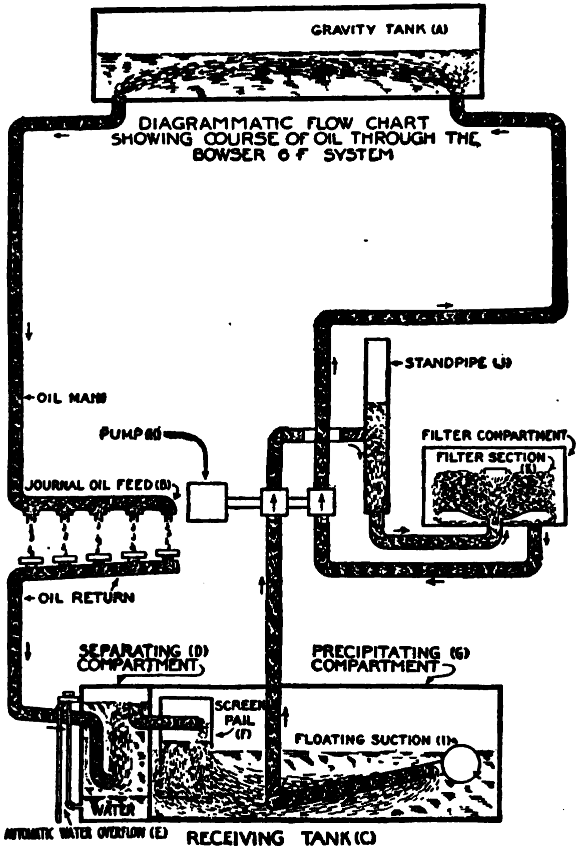


FIG. 15. SEC. 7e.—Simplified oil flow diagram of system shown in Fig. 14. Sec. 7e.

tion from the frequent churnings and the possibility of moisture getting into the system from condensed steam or from other sources.*

NOTES ON GRAVITY OILING SYSTEMS.—Combination oil cups and sight-feed needle valves should be used at all points of lubrication. The oil cups should always be kept full and ready for instant use in case the circulating system fails.

* NOTE. See p. 433 for oil specifications.

The gravity reservoir should have a large capacity, so as to provide a safe margin of safety for the supply.

Gravity systems are built either to supply one engine or a number of engines and machines from the same system. The size of the system is rated by the number of points of application of the lubricant or by the number of gallons of oil fed per hour or working day.

In large installations it is well to take a sample of the system oil every day or at frequent intervals for test, so that the need for fresh oil will be quickly detected by an unduly increased viscosity.

For all gravity feed systems the point of entry of the oil to any bearing should be at the point of minimum pressure in the oil film.

FILTERS FOR CIRCULATING SYSTEMS.—A properly designed system should be equipped with sufficient filtering capacity to permit the continuous feeding of a copious stream of clean oil to all bearings. The following table gives the average capacity required for a system to supply slow, medium-speed and high-speed engines:

FILTERING CAPACITIES FOR GRAVITY SYSTEMS TO SUPPLY SLOW-SPEED AND MEDIUM-SPEED ENGINES *

Engine horse-power	Capacity of filtering unit gallons per hour	Engine horse-power	Capacity of filtering unit gallons per hour
100	4.25	1000	21.50
150	5.00	1150	25.00
200	6.00	1300	30.00
250	7.00	1500	40.00
350	10.00	2000	75.00
500	12.00	2500	110.00
750	18.00	3000	145.00
HIGH-SPEED ENGINES *			
100	5.5	350	13.00
150	6.5	500	15.50
200	8.0	750	24.00
250	9.25		

* NOTE. Engines running at 150–300 R. P. M. are classed as *high speed.*
Engines running at 125–150 R. P. M. are classed as *medium speed.*
Engines running at 75–125 R. P. M. are classed as *slow speed.*
Engines running at up to 75 R. P. M. are classed as *very slow speed.*

LOCATION OF RESERVOIR.—Considerable latitude may be assumed in the location of the reservoir, filter and circulating pump. It is very important, however, that the gravity reservoir be placed at the highest point in the engine-room, so as to produce a good head of pressure for a positive and uniform flow of oil to all of the bearings.

In small systems the filter is often used as the reservoir, and is located in an elevated position. The filter should be easily accessible for

frequent cleanings, as the success of these systems depends upon a clean filter of sufficient capacity.

MAIN VALVE.—The main supply pipe from the reservoir should be equipped with a valve, to permit the shutting off of the flow to the whole system.

FLOODED LUBRICATION

Flooded lubrication consists in supplying a continuous stream of oil to the bearings, but differs from forced-feed lubrication in that the oil is circulated at a low pressure. The flow is usually much less in quantity as compared to forced feed.

The circulation of the oil may be maintained by a pump or by a gravity tank (gravity feed). Flooded lubrication is often used for large roller bearings, as found in the step bearings of vertical turbo-alternators, and a system similar to the ordinary gravity feed is used, the difference being that the oil is piped directly to the bearing in a continuous stream, instead of through sight feeds. There is usually a cooling coil in the system to reduce the oil temperatures.

Roughly speaking, about one-quarter as much oil is circulated, for the same amount of bearing area, in a system supplying flooded lubrication as in one supplying forced-feed lubrication.

WEAR OF OIL.—Experiments that have been made by Professors Carpenter and Sawdon at the Cornell University, to determine whether lubricating oil "wears out" when used continuously in circulating systems, have indicated that, while the oil gained in gravity and viscosity, due to its volatile constituents having been driven off by the heat in the bearings, nevertheless the friction tests gave a slightly lower coefficient of friction at low pressures, and a slightly higher coefficient for high bearing pressures with samples taken from a well-designed central oiling and filtering system supplying flooded lubrication, as compared to tests made on samples of the same oil that had not been used in the system. Enough fresh oil must be frequently added to the system to maintain fairly constant viscosity.

(4) FORCED-FEED OIL LUBRICATION

When bearing pressures and speeds are high, it is necessary to force oil under pressure into the bearings, and this type of lubrication is called "forced feed."

RATE OF FLOW.—The rapidity of flow of the oil through the bearings must not be excessively high, There is a rate of flow for each operation that will produce the best efficiency. The oil must have sufficient time to absorb the frictional heat and thus carry it away from the bearing.

PRESSURES.—For horizontal bearings, forced-feed oil pressures range from 15 to 30 pounds to the square inch. For thrust and step bearings the pressures are much higher, depending upon the load carried.

POINT OF ENTRY.—In designing a forced-feed system, care must be taken not to introduce the oil into the bearings at such points that it will pass through the low-pressure areas of the oil films, causing counter-currents in the films and escaping without carrying off its proper share of frictional heat.

This often results in an overheated bearing, although there is apparently a sufficient amount of cool oil being circulated through the bearing. Some authorities recommend that the point of entry be located at a point 45 degrees off the vertical axis of the bearing, on the "on side" of the film, as indicated in Fig. 16, Sec. 7e. The best practical results seem to be obtained by locating the point of entry in the "on side" at the horizontal axis, as indicated at *A* in the figure.

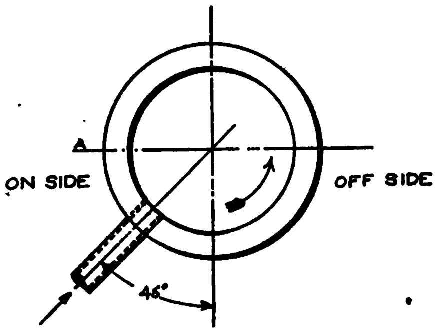


FIG. 16. SEC. 7e.—Point of entry.

LUBRICATING OIL FOR FORCED FEED.—The oil used in all forced-feed oiling systems must be an absolutely non-emulsifying oil. For the usual forced-feed installation, an oil of 150 to 165 Saybolt viscosity at 100° F. (P. B.), or 200–210 Saybolt at 100° F. (A. B.) will give the best results. The oil should have a low-gumming test and be free from any impurities. It is needless to state that the oil must be a strictly straight mineral oil.*

COOLING.—In most systems the hot oil coming from the bearings is passed through a cooling tank, and cooled by coils of pipe containing running water.

WATER-JACKETED BEARINGS.—One of the results accomplished by forced-feed lubrication is the rapid reduction of frictional heat in the bearing by the rapid flow of the oil through the bearing. For general practice, bearings using forced-feed lubrication do not require any additional cooling effect, but for very high pressures and speeds, water jackets must be used.

The specific heat of water at its maximum density is taken as 1.000, while the specific heat of the average petroleum lubricating oil at 60°

* NOTE. See p. 433 for forced-feed lubricating oil specifications.

Fahr. is approximately 0.4175. Since the specific heat of a liquid is a measure of its thermal or heat-absorbing capacity, it can readily be seen that a water jacket will carry off a large percentage of bearing heat. The cooling water is carried through small pipes, or channels, located as closely as possible to the lining of the bearing. Great care must be exercised not to permit any water entering the system and mixing with the oil, as the result will be a large increase in the friction produced in the bearings, due to the reduced efficiency of the oil, and this increase in frictional heat will defeat the very purpose of the water jacket.

For tests showing the actual increase in friction due to various percentages of oil and water, refer to the curve plotted from running tests, as shown in the section under the heading of " Marine Lubrication." (See index.)

PRESSURE OIL FILM LUBRICATION

PRESSURE OIL FILM LUBRICATION.—The fact that under favorable conditions fluid pressure is generated in the oil film of a journal bearing has been definitely determined by experimentation. This section has reference to the pressure in the film that is produced by the rotative action of the journal, and does not refer to forced-feed lubrication, which has been discussed in another section.

The subject of pressure in the oil film is referred to also in the Theory of Lubrication chapter.

Fig. 17, Sec. 7e, illustrates the formation of the pressure film in a journal bearing when the brass is on the top of shaft. When the shaft revolves, the oil adhering to it is forced by its rotation in under the brass on the " on side." Here it accumulates pressure until it lifts the brass sufficiently to permit the oil to escape at the " off side " and at the ends.

If a hole is drilled at the top of the brass, the oil will spurt out through it. The pressure can be measured by a gauge, just as other fluid pressure. The curve shown in the upper part of the figure is typical of he curves obtained by Beauchamp Tower in his experiments. His esults were obtained by actual experiment, while Prof. Osborne Reyolds, in a paper on " The Theory of Lubrication," showed that a pressure curve obtained by calculation closely approximated the experimentally obtained curve of Tower's.

An essential condition for the formation of a pressure oil film between two surfaces is that the surfaces must have sufficient free play so that they can adjust themselves to produce a slight inclination to each other. With a journal bearing, the pressure film takes the form of a curved wedge, due to the slight shifting of the centre of the shaft in relation to the centre of the brass, as the figure shows.

FRICTIONAL RESISTANCE.—Prof. Osborne Reynolds, in his paper on " The Theory of Lubrication," showed that the friction under perfect pressure film conditions was merely due to the viscous flow of the oil. This may be described as the internal friction of the lubricant. The viscosity of an oil is a factor depending upon the cohesive and adhesive properties of the particles composing the oil, as has been described in another section of this book. The " property of adhesion " is important, in that upon this factor dependence must be placed to cause the oil to

adhere to the journal, and thus be drawn under the brass, where the accumulated pressure is produced. Also the "cohesive properties" are important in maintaining this pressure film, in that this property offers resistance to tear or destruction of the film. These two factors, as has

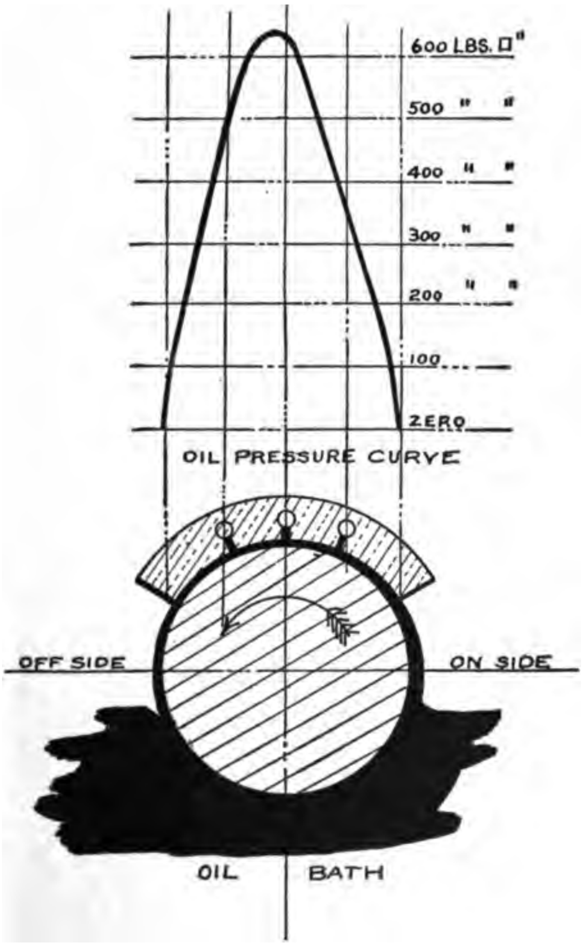


FIG. 17. SEC. 7e.—Formation of the pressure film in journal bearing.

been described, are required in sufficient degree to create and maintain the pressure film. However, the frictional resistance met with in a bearing having a pressure film is that due to the viscous flow of the oil. Thus one condition offsets the other. As a result, in order to get results, the oil used should have as low a viscosity at the working temperature as will

form the film and maintain it, and any excess viscosity will add friction to the bearing.

EFFECTIVE BEARING AREA.—In tests run by Professor Goodman and quoted by Mr. H. T. Newbigin in explaining the principle of the Mitchell journal bearing, the effect of reducing the width of a bearing was demonstrated as follows:

Two tests were run. In the first, the shaft was 2 inches in diameter, the length of the journal was 4 inches, the speed 233 R. P. M. and the total load 550 pounds. It was found that when the projected width of the brass was 2 inches, the actual friction was, or resistance to the shaft turning was, 2.85 pounds, and the average nominal pressure per square inch was 68.8 pounds. When the width of the brass was reduced to 1/2 inch, the friction was only .84 pound, while the total pressure per square inch was 275 pounds.

The conclusions reached are that the effective supporting area in a journal bearing is a narrow strip, and that the remainder acts as a brake on the rotation of the shaft. This principle is made use of in the design of the Michell journal bearing, the necessary wedge of oil being produced by a slight displacement of the centre of the shaft in relation to the brass. In this bearing the brake surface is eliminated by surrounding the shaft with a number of splints or segments, each pivoted so as to be able to tilt and produce as many wedges as there are segments around the shaft.

Also see index for Kingsbury Bearing.

*SUMMARY OF SPECIFICATIONS FOR LUBRICATING OILS FOR FORCED FEED AND CIRCULATING SYSTEMS

Grade	Type	Flash °F.	Fire °F.	Viscosity Say. at 100 °F. seconds	Color Nat. Pet. Assoc.	Pour Test °F. not above	Acidity Mmgs. KOH to neutralize one gram	Emulsifying properties. Oil must separate in 30 minutes from:
B	Extra light	315	355	140–160	Not darker than No. 5	35	Not more than 0.07	(1) Distilled water. (2) 1 per cent salt solution. (3) Normal caustic soda solution.
C	Extra light	315	355	140–160	Not darker than No. 5	35	Not more than 0.05	(1) Distilled water. (2) 1 per cent salt solution. (3) Normal caustic soda solution (4) The demulsibility not less than 300.
B	Light	325	365	175–210	Not darker than No. 5	35	Not more than 0.07	Same as for B extra light.
C	Light	325	365	175–210	Not darker than No. 5	35	Not more than 0.05	Same as for C extra light.
B	Medium	335	380	275–310	Not darker than No. 5	40	Not more than 0.07	Same as for B extra light.
C	Medium	335	380	275–310	Not darker than No. 5	40	Not more than 0.05	Same as for C extra light.
B	Heavy	345	390	370–410	Not darker than No. 5	45	Not more than 0.07	Same as for B extra light.
C	Heavy	345	390	370–410	Not darker than No. 5	45	Not more than 0.05	Same as for C extra light.
B	Extra heavy	355	400	470–520	Not darker than No. 6	50	Not more than 0.07	Same as for B extra light.
C	Extra heavy	355	400	470–520	Not darker than No. 6	50	Not more than 0.05	Same as for C extra light.

* These tests are a summary of the specifications issued by the Committee on Standardisation of Petroleum Specifications, April, 1920, for oils used by the United States Government, for lubrication of turbines, dynamos, high-speed engines, etc., and for forced feed and circulating systems. Class (C) oils are for cases requiring a better oil than Class (B) oils.

(5) SPLASH-FEED OIL LUBRICATION

While splash feed is used only on individual units, it may supply lubrication to several bearings in that unit. The lubrication of the crank pins of certain types of engines is accomplished by splash feed. The engine frame is made to form a reservoir, and the crank at each revolution dips into the oil, throwing it onto the rubbing surfaces. Either horizontal or vertical stationary engines may be equipped with this form of lubrication. Many types of internal-combustion engines use the splash system for main bearings, crank, cross-head and wrist-pin lubrication. The cylinders of many vertical internal-combustion engines are also lubricated splash feed.

Splash feed is apparently very economical and not wasteful of oil, but it has many disadvantages. The oil in the reservoir soon becomes saturated with particles of dirt and metal from the wear of the bearings, and it is useless to expect satisfactory or efficient work from dirty oil. Steam, leaking past the piston-rod packing box and condensing in the crank-case, mixes with the oil, and unless the oil is a strictly neutral, non-emulsifying oil, untreated and free from any compounding, the result will be a thick, emulsified mass. Very often the emulsification of oil used in crank-case, splash-feed lubrication is caused by the use of excessive amounts of boiler compound in the boiler. This compound may be carried over with the steam by excessive priming in the boiler, and then, after leaking past the piston-rod packing box into the crank-case, may combine with the oil and cause it to form a soapy, emulsified mass. This condition is, of course, immediately blamed on the oil, but if it is a pure, strictly neutral oil, the location of the steam separator, its condition and the boiler compound should be investigated as being the real cause of the complaint.

The fact that the engine frame is generally warm, prevents the oil from being sufficiently cooled in the crank-case, and this is a very serious objection to splash-feed lubrication.

(6) SPECIAL METHODS, BEARING-OIL LUBRICATION

SELF-OILING CAPILLARY BEARING.—Fig. 18, Sec. 7e, and Fig. 19, Sec. 7e, show a type of bearing known as the Dodge Capillary Self-Oiling Bearing, which is suitable for use on line shafting. This bearing is equipped with an opening at the bottom. In this opening a

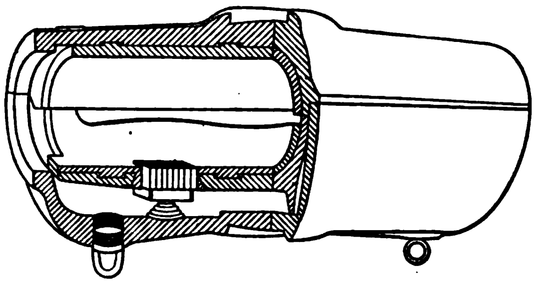


Fig. 18. Sec. 7e.—Dodge capillary self-oiling bearing. (Courtesy of Machinery.)

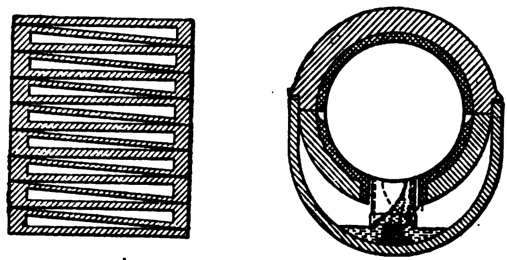


Fig. 19. Sec. 7e.—Principle of operation of capillary bearing. (Courtesy Machinery.)

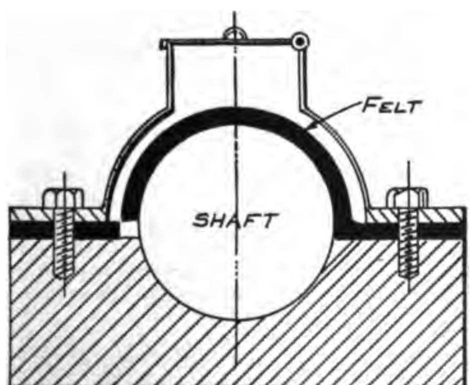


Fig. 20. Sec. 7e.—Method of applying oil lubrication to a semi-enclosed bearing.

wooden block is inserted and extends down and dips in a reservoir. A spring holds the block against the shaft. The block has a series of slots cut in it, as shown in Fig. 19, Sec. 7e, through which the oil tends to rise in the narrow end, due to capillary attraction, and thus the oil is carried up to the shaft and bearing. One of the advantages claimed for the bearing is the absence on agitation of the oil in the reservoir.

SEMI-ENCLOSED BEARING LUBRICATION.—Frequently semi-enclosed bearings are encountered which are difficult to lubricate. Such a bearing as shown in Fig. 20, Sec. 7e, may be successfully lubricated with oil by using felt, as indicated in the drawing. The oil may be held on the bearing by this method, and, while it does not produce the best results, it nevertheless accomplishes the purpose. Fresh oil is supplied through the oil cap onto the felt.

(7) WICK OIL FEEDS

WICK FEEDS, PRINCIPLE OF.—Wicks and pads, when exposed to the atmosphere, absorb moisture. They should be well dried and wetted with the oil to be fed before they are in shape to permit free flowing of the oil.

Worsted strands are composed of comparatively coarse fibres and will not give as powerful a lift as will finely woven or spun cotton yarns.

Wick lubricator boxes should be made shallow, to prevent the deposit of gumming and sticky deposits at the bottom, and they should be frequently cleaned out.

The quality and fineness of wool strands used for wick feeds have a direct effect upon the rate of syphoning. As much as 100 per cent. dif-

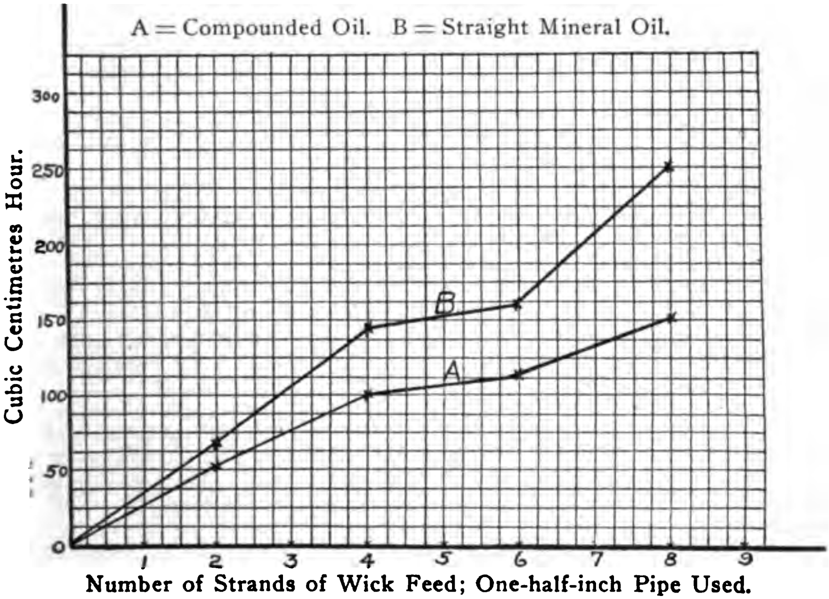


FIG. 21. SEC. 7e.—Relative amounts of oil fed by wick feeds.

ference in syphoning rates has been observed between various types of wicks.

The curves shown in Fig. 21, Sec. 7e, illustrate the relative amounts of oil fed by wick feeds containing various numbers of wick strands. For curve *A* a compound marine engine oil was used, containing about 18 per cent. of blown rapeseed oil compound. This oil had the following general tests:

700 Vis. Say. at 100° Fahr. (A. B.)
19 Grav.
350 Flash.

For curve *B* an oil having no compound and the following general tests was used:

320 Vis. Say. at 100° Fahr. (A. B.).
22 Grav.
350 Flash.

The pipe containing the wicks was 1/2 inch in diameter.

In connection with numerous tests run by the U. S. Navy and others, the following general conclusions were unanimously arrived at:

(*a*) The straight mineral oil will maintain a lubricating film and the turning on of a water service will not destroy the film. (Marine Engine Lubrication.)

(*b*) In general, the lower bearing temperatures were obtained with the straight mineral oil rather than with the compounded oil.

(*c*) When the water service is shut off, the oil film will quickly re-form with the straight mineral oils, and the bearing temperatures will remain normal.

Note. These conclusions apply to lubrication of marine engines.

WICK-FEED TEST.—(Committee on Standardization of Petroleum Specifications, 1920):

"An oil container made of brass of capacity of about one quart is fitted in the centre with a brass tube of 1/2 inch internal diameter, which serves as an oil-way and which feeds into a graduated glass cylinder, where the quantity of oil fed by eight strands of worsted zephyr is measured. At the beginning of the test the wick should be dipped in the oil and the lift of the wick should be maintained at from 1/2 to 1/4 inch. The wick should be supported by a copper wire bent in a hock which grips the outlet end of the wick below the level of the oil, as is the usual manner in a wick feed.

"The worsted zephyr shall be of the best quality, pure, long fibre, cream-white fine wool, thoroughly washed, scoured and carded. It shall be in its natural condition; not dyed nor subjected to any chemical process. Strands shall be four-ply soft spun and twisted. The separate plies shall be of uniform thickness throughout their entire length."

Also see p. 767 for wick-feed tests.

COLLAR BEARINGS

There is little aid given by the contact surfaces of a collar bearing towards lubrication. Usually forced or flooded lubrication is necessary for the lubrication of this type of bearing.

(8) LUBRICATING OILING SYSTEMS FOR ENGINES (SELF-CONTAINED)

MAIN TYPES.—The main types of self-contained lubricating systems in use in various engines are as follows:

(*a*) Splash lubrication.
(*b*) Bath lubrication.
(*c*) Pressure lubrication.
(*d*) Gravity, with separate or automatic water separators for vertical engines.
  1. Self-contained strainer and overflow.
  2. Exterior strainer and overflow.

(*a*) Fig. 22, Sec. 7e, shows a horizontal steam engine equipped with splash lubrication. The crank disc dips into the oil in the crank-case to

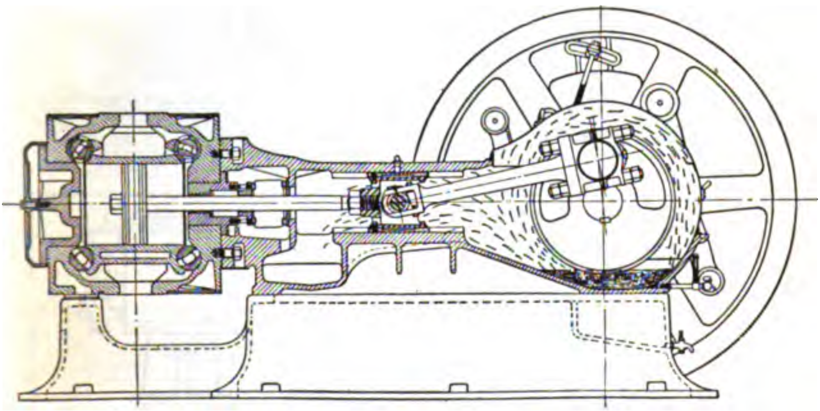


FIG. 22. SEC. 7e.—Cross section of a Corliss engine. (Splash lubrication.)

a depth of about 2 inches and throws the oil which it picks up onto the cross-head guides and cross-head, while oil thrown into the pockets within the frame feeds the main bearings.

(*b*) Fig. 23, Sec. 7e, shows an Ingersoll-Rand Compressor equipped with bath lubrication. The crank disc dips into the oil in the crank-case and carries it up to the wiper at the top, where it is caught and carried to the bearings and piston-rod.

(*c*) Fig. 24, Sec. 7e, shows a Sturtevant vertical engine equipped with a pressure and filtering system. Filters and water separators are provided to remove dust and condensation water, which is common in these types of engines.

A chain-drive pump raises the oil through tubes to the bearings.

(*d*) Fig. 25, Sec. 7e, shows a Skinner engine equipped with a pump and oil-and-water separator. One of the great difficulties with vertical engines is the emulsion which may be formed in the base, due to the

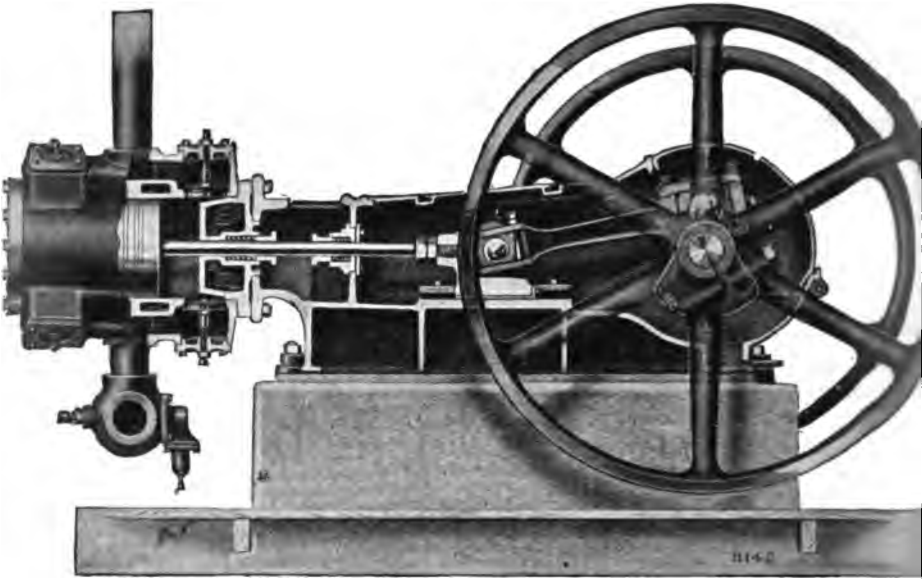
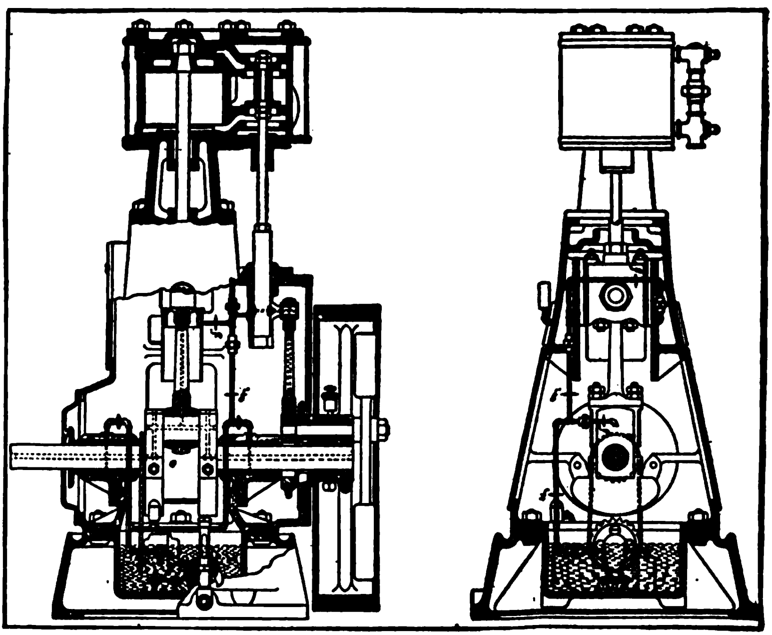


FIG. 23. SEC. 7e.—Longitudinal section. Belt driving straight line compressor. (Bath lubrication.)



[illegible]. 24. SEC. 7e.—Sectional view of Sturtevant vertical engine, showing pressure oiling system.

churning of the oil with the condensation from the steam from the piston-rods. Reference to the curves in another section of this book will illustrate the effect of water and emulsions on the lubricating efficiency of an oil. (See index.)

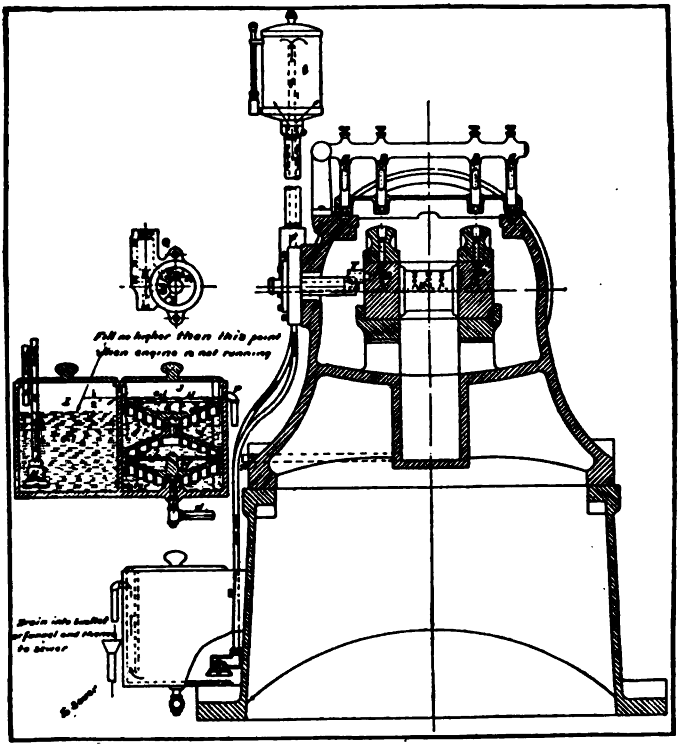


FIG. 25. SEC. 7e.—Skinner engine equipped with a pump and oil and water separator.

GREASE CUPS AND GREASE APPLICATION METHODS

CLASSES OF GREASE CUPS.—In general, the various types of grease cups can be classified into four different divisions:

1. Plain hand compression.
2. Gravity, or vibration, feed.
3. Automatic compression (spring or air types).
4. Compression type, with automatic feed control.
5. Screw feed, marine type, hand operated.

(1) PLAIN HAND-COMPRESSION CUPS.—The plain hand-compression type of cup has up to the present time been the type most generally in use. This has been due not to its efficiency, but because it is a smaller type than the others, and in many places space will not permit the use of some of the other larger types; also because it is cheapest.

Fig. 26, Sec. 7e, and Fig. 27, Sec. 7e, show plain compression grease cups. The cup shown in Fig. 27, Sec. 7e, is known as the ratchet cup. It is equipped with a ball check valve and is intended for use on circulating pumps and other similar points where water might back up into the body of the cup.

Fig. 26. Sec. 7e.—Plain compression grease cup.

In the general type of compression cup, the bonnet or top is filled with grease. When the top is turned down, the grease is forced into the bearing. The chief fault with this type of cup is the unevenness of feed, due to the fact that when the cup is screwed down, more grease than is required for lubrication at that particular time is forced out, and as a result the grease is usually squeezed out around the collar and wasted.* This type of cup requires frequent attention and is wasteful. The cup has a field, however, in those places where its size, simplicity and cost is an advantage. It may be made of pressed steel, cast iron or brass, ranging in capacities from 1/4 to 8 ounces. There is the plain type, also other types, with leather and frictional washers and locking devices for use in parts where there is exceptional vibration.

(2) GRAVITY-FEED CUPS.—The gravity-feed type of cup is particularly adapted for line shafting lubrication. It is also extensively used for cranes and other machinery where the cup can be installed in a manner to permit the rod in the cup reaching the journal.

Fig. 28, Sec. 7e, and Fig. 29, Sec. 7e, show two makes of funnel cups. In these cups a soft copper rod is provided, as shown. This rod is cut to the correct length to permit its end to rest lightly on the revolving shaft. Gravity, the vibration of the rod, and some heat carried up the rod to the grease all tend to cause the grease to flow down the rod and into the bearing. There is also some vacuum, caused by the revolving shaft, which assists the grease feed. Fig. 30, Sec. 7e, also shows a funnel cup.

This type of cup is not classed as an automatic cup, but it has some good automatic features. It feeds only when the shaft is revolving. It

* Note. See index for "Theory of Grease Lubrication."

requires no adjustment until the cup needs refilling. For the lubrication of shafting, one filling of the cup should last about one to four months. It can be used on high-speed work with success, and has proven very satisfactory and efficient. It is usually made in the five-ounce size. A No. 2 grease is the average consistency used, although as the installation may require, softer or stiffer numbers are used. The soft copper rod takes up the rubbing wear, thus preventing scoring of the shaft.

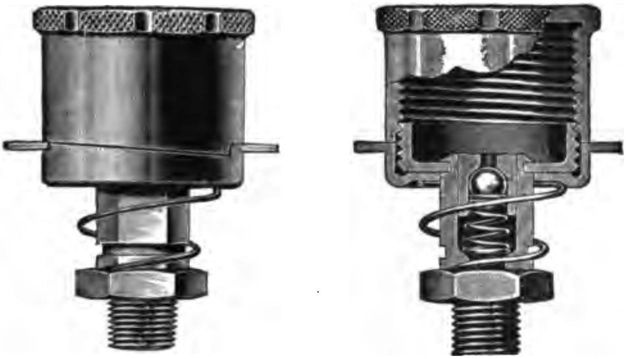


FIG. 27. SEC. 7e.—Plain compression grease cup. The cup shown above is known as a ratchet cup.

FIG. 28. SEC. 7e.—Funnel cups.

FIG. 29. SEC. 7e.—Funnel cup 5 oz. capacity.

(3) AUTOMATIC COMPRESSION CUP.—This type of cup is adapted for moving bearings, such as crank-pins, cross-heads, slides, eccentrics, etc. They are also used on stationary bearings. The pressure for feeding the grease to the bearing is supplied by springs or compressed air. The feed is, therefore, more or less automatic.

(*a*) In the standard spring type of cup, such as is shown in Fig. 32, Sec. 7e, there is a threaded plunger or piston, with a leather washer and a spring back of the plunger to supply pressure when the spring is compressed. The cupped leather plunger provides a grease-tight joint,

to prevent the grease from leaking back of the piston on the spring side. There are several types of these cups. The compression cups shown have a provision for regulating the amount of grease fed to the needs of the bearings; by turning the screw valve in the shank, the flow can be partially cut off. The set bar on the handle provides a method

Fig. 30. Sec. 7e.

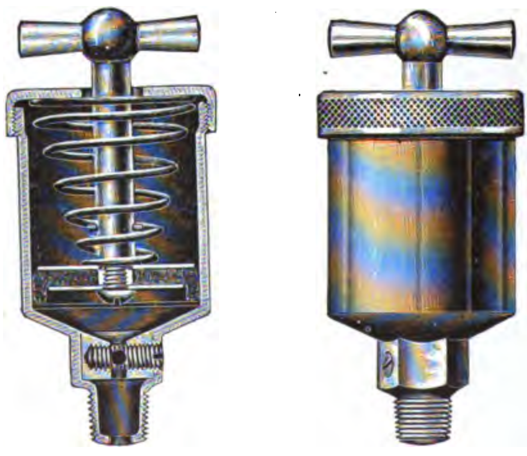


Fig. 31. Sec. 7e.—Continuous feeding cup.

for stopping the downward feed of the piston at any desired point, at which the feed of grease will be stopped. In the cup shown in Fig. 31, Sec. 7e, there is no provision for stopping the movement of the plunger, and the spring, therefore, continues pushing out the grease until the cup is emptied. In filling this cup, before unscrewing the cap, the handle is pulled up until the pin appears through the slot in the cap, when a slight turn of the handle allows pin to rest on the top of the cap, locking back the plunger in its highest position. The cap is then unscrewed and

the cup filled. The cup shown in Fig. 32, Sec. 7e, is operated as follows: When filling, the thumbnut *A* is turned to the right until the plunger is drawn to the top of the cup; the cover is then unscrewed and the cup filled with grease. The cover is then replaced and pressure

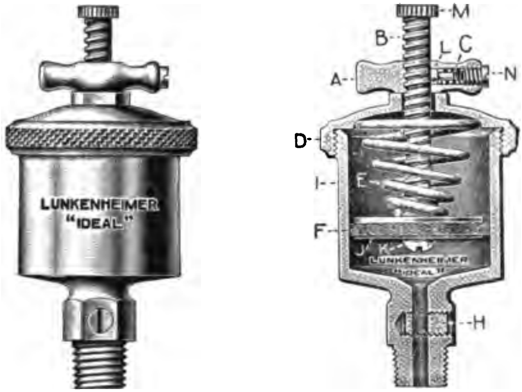


Fig. 32. Sec. 7e.—Spring compression automatic grease cup.

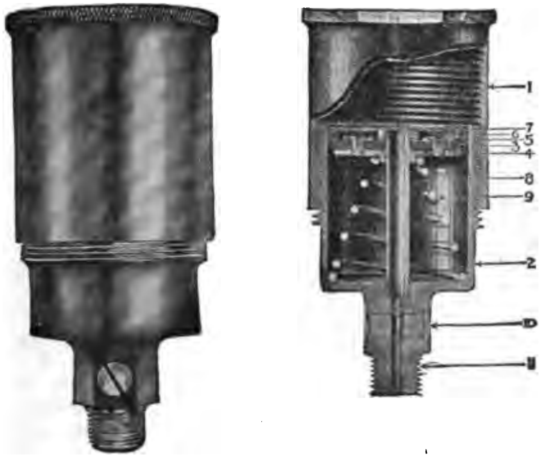


Fig. 33. Sec. 7e.—Spring compression cup. (Cap fill.)

put onto the grease by screwing thumbnut *A* up to the top of stem *B*. The rate of feed must be regulated by screw *H*.* When it is desired to stop flow of the grease, thumbnut *A* is turned down to the cover.

* Note. It must be remembered, however, that a setting of the screw *H*, to check the flow when the spring is under full compression, will not be the correct setting to give the same flow of grease when the spring is partially expanded and the pressure on the grease reduced. Thus, the feed of the grease is subject to considerable fluctuation, unless frequent adjustments of the screw *H* are made.

Fig. 33, Sec. 7e, shows a type of spring compression cup where the grease is filled into the cap of the cup. The plunger in this case works in the cup body upward from the bottom. There is a hollow tube extending down through the centre of the cup body, plunger and spring, which acts as an outlet orifice for the grease. The plunger action in this type is the reverse from that described in the preceding cups, the grease being forced upward against the cup cap, and from thence down through the outlet tube.

The spring-compression type of cup requires much less attention than a hand-compression cup (usually three or four adjustments will suffice for emptying the cup), and in most places this cup will provide a more satisfactory form of lubrication with a decided saving of grease than can be obtained when using the hand-compression cup. However, the same objection stands against this type of cup as against the hand-compression cup, namely, the feed is not constant, due to the variation of pressure exerted by the spring when changing from full compression to full extension. This type is also more expensive than the plain type.

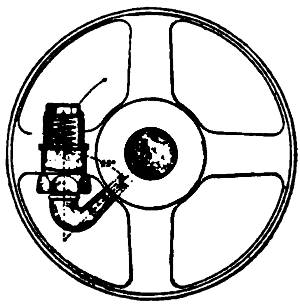


FIG. 34. SEC. 7e.—Loose pulley, grease lubricator, compressed air cup. (Courtesy Hunter Pressed Steel Co.)

(*b*) There is another form of spring automatic cup, known as the continuous-feed type. This cup is designed similarly to the standard spring type, except that an attempt is made to obtain a constant spring pressure until the cup is emptied. The cup is intended for use in places where it is inaccessible for adjustments, but it is not uniform in feed, and is not recommended in preference to the standard spring type.

(*c*) The compressed-air cup is another form of automatic-feed cup. The body of the cup is threaded on the inside, the top screwing down into the grease-filled body, hus providing the compression, which acts on a loose plunger, or disc, lue to the compressed air, which is trapped in the top. Near the bottom of the cup top is a disc, which provides for the distribution of the air pressure over the grease. The cup may be adjusted to give varying pressure. The grease is moved to the bearing in a body, and, due to the equalized pressure over the grease, there is no change in its consistency, which will often occur in the case of a mechanical or spring-pressure cup. This type of cup is economical and requires less attention than other types of cups. Fig. 34, Sec. 7e, shows an air-compression cup of the air-spring type arranged for loose pulley lubrication.*

* NOTE. Air-compression cups are of three general types, viz.:

1. Philadelphia cup, which has a loose disc, suspended from a false head in the cup cap.

2. Air-spring cup, which has two discs, with a spring between them, to bring the lower disc back to its starting point. These discs are not fastened to or held in the cap. See Fig. 34, Sec. 7e.

3. Industrial air cup (see Fig. 35, Sec. 7e). This cup contains no springs or discs, only a sliding piston.

Fig. 35, Sec. 7e, shows a sectional and an open view of the Industrial air-compression cup. This cup differs from other cups of the air-compression type in that there is only one moving part; namely, the piston. This is a closed metal piston, the thickness of which is determined according to the air volume in the cap of the cup. When the cup is filled, as shown in the figure, the piston is in its lowest position in the cup cap. The cap is then placed on the body, and the air pressure placed on the piston by screwing the cap into the cup body, thus compressing the air behind the piston. Very high compressions can be obtained with this cup, and a

FIG. 35. SEC. 7e.—Industrial air compression cup.

maximum delivery of grease is claimed for the cup, with a minimum of adjustment. The manufacturers claim that the piston of this cup will always return to its bottom position, and a particular feature claimed for the cup is that when it has reached its lowest position a vacuum is formed behind the piston, preventing it from falling out of the cup cap, which is a source of objection to some types of cups, which have no means of preventing the internal parts of the cup from falling out of the cap and being lost or getting into moving machinery. There is no tendency in this type of cup for the grease to leak past the piston and affect the compression by getting into the air chamber. This cup is also designed

with a so-called "vacuum breaker" in the lower part of the cup body.* This vacuum breaker is designed to facilitate the screwing off of the cup cap after the cup has been emptied.

In the usual air cup, installed on a bearing, after it has become emptied and the cap is unscrewed, the fact that no air can be sucked through the bearing into the lower part of the cup creates a vacuum in the lower part of the cup, which increases as the cap is raised, and in a large cup offers a considerable resistance to the unscrewing of the cap. The vacuum breaker used on this type of cup is designed to break this vacuum, by admitting air below the piston when the cap is being screwed off, making the refilling of the cup much easier and quicker.

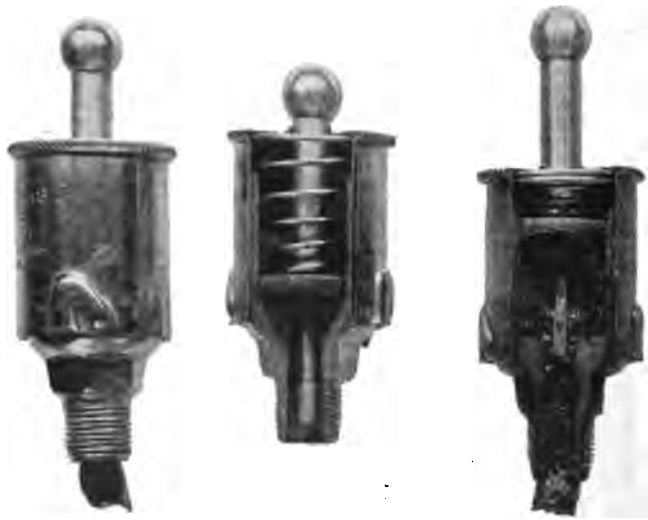


FIG. 36. SEC. 7e.—Uniflow grease cup.

(4) COMPRESSION CUPS, AUTOMATIC FEED CONTROL, UNIFLOW TYPE.—Fig. 36, Sec. 7e, shows a sectional and outside view of the Uniflow grease cup of the plunger-control type.

The operating principle of the Uniflow type of cup is to control and maintain uniform the flow of grease from the cup, by proportioning the area of the exit orifice against the varying spring pressure acting on the grease, as the piston moves from full compression, to the end of its stroke. This feature is obtained by means of a tapered orifice at the bottom of the cup, within which a controlling plunger plug moves. When the cup is filled with grease and the cover is put in place, by pushing it into the body of the cup until it locks, the piston is pushed up, carrying the regulating plunger plug to the small upper end of the tapered orifice, as indicated in the cut-out section, and, as the spring pressure, due to full com-

* Not shown in cut.

pression, is highest at that time, the plug restricts the outlet to its minimum. As the piston moves down and the spring pressure is reduced, the area of the exit orifice is increased proportionately, by the movement of the plug, which is carried by the piston, and which thus moves down in the gradually widening tapered orifice thus offering a larger opening for the grease to pass through. The flow of the grease can be varied according to the taper and set of the orifice, to meet any specified bearing lubrication requirements. A feature of this cup is that the feed may be so regulated, by proportioning the free area of the orifice, that the cup will supply grease to a bearing only when the grease film is in motion, thus preventing flooding on the bearing. This cup requires no adjustment, and only requires attention for filling. The amount of grease in the cup and the time for refilling is indicated, by the position of the indicator, which moves above the cup, with the piston.

FIG. 37. SEC. 7e.—Uniflow grease cup.

The Uniflow cup, with the plunger and tapered orifice control, is also manufactured in the various sizes in the form as shown in Fig. 37, Sec. 7e. With this type of cup, the screw on the piston stem is only used to hold the piston in the cap, when the cap is to be removed for filling the body of the cup with grease and after the cap is replaced, so that the plunger plug enters the top of the tapered orifice, the set nut, on the top of the piston-rod, is turned up to the top of the piston, and no further use of the adjustment screw is required until the cup is empty, which is indicated by the position of the rod.

FIG. 38. SEC. 7e.—Uniflow grease cup, sliding valve type.

Fig. 38, Sec. 7e, shows the Sliding-valve type of Uniflow cup, which operates as follows: The exit orifice is balanced against the spring pressure, as in the plunger type of cup, there being two outlets at the bottom of the cup, controlled by a double-ported valve, which has a travel, so as to move its ports from an entirely closed position, to a full open position across these outlets. There is a center tube, over which the piston slides, while within the piston-rod there is a plunger, which travels down with the piston, but inside of the tube. There is a flat spring in this tube, which is fixed to the sliding valve below, and which tends to hold it in a closed position, and as the piston moves down, the plunger within the tube, as previously described, slides against this flat spring, thus moving it over in the central tube and actuating the valve proportionately to the piston travel. A feature of this cup is that its rate of feed may be set when it is filled, and it will maintain this feed uniformly without any further adjustment until the cup is completely empty. This feed may be set to deliver any definite quantity of grease, from the smallest amount to the full flow of the orifice. The set of the cup is accomplished by the set screw, shown at the side, by which any

desired lead may be given to the valve and the port opened, this lead being maintained throughout the emptying of the cup, and the feed thus set being exactly the same as the feed at the end of the piston travel. In a test of this cup, exhausting into the open air, without any resistance other than the valve mechanism of the cup, a uniform flow of grease, with a six-ounce cup, for a period of 72 3/4 hours was obtained without any adjustment.

FIG. 39. SEC. 7e.—Screw feed. Marine type grease cup.

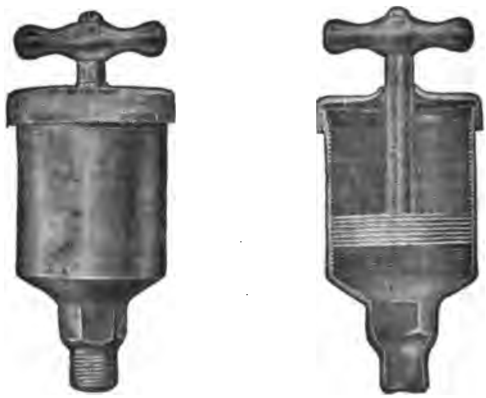


FIG. 40, SEC. 7e.—Screw plunger feed grease cup. Marine type.

(5) SCREW FEED OR MARINE TYPE OF CUP.—In this type of cup the body is threaded on the inside and the plunger on its outer diameter. To operate, the handle of the plunger is turned down, thus forcing the grease to the bearing. This is really a form of hand-compression cup. It is particularly suited for use on marine engines or other places where it is necessary to force grease some distance or to feed grease to bearings

at certain intervals. It is found on mining machinery. It is usually made in capacities of 1/8, 1, 1 1/2, 3, 6 and 10 ounces. Typical cups of this type are shown in Fig. 39, Sec. 7e, and Fig. 40, Sec. 7e.

METHODS OF LUBRICATING LARGE, OPEN BEARINGS.—For the lubrication of large, slow-moving bearings, that are equipped with open grease wells in the bearing cap, or are merely furnished with a light bearing cover instead of a bearing cap, it is customary to apply the lubricant required by one of the following described methods:

(*a*) By fixing a piece of oil-soaked felt in contact with the exposed upper surface of the journal, as is shown in Fig. 20, Sec. 7e.

(*b*) By placing a stiff, heavy grease in the well, in direct contact with the upper surface of the journal.

(*c*) By filling the well with waste, which is oil-soaked, and then feeding oil onto the waste as needed.

(*d*) By spreading grease over the upper surface of the journal by means of a "retarder." Ordinary, medium melting-point grease may be applied in this manner with good results.

Methods (*a*) and (*d*) are by far the best, and the selection of the method to use depends upon whether it is desirable to use a grease or an oil.

GREASE RETARDERS.—Retarders are made of copper-wire gauze, perforated leather, perforated wood or perforated copper sheets. These retarders are bent to conform to the surface of the journal, and are made to fit the entire width of the open well.

The grease is fed by means of a compression cup, or by other means, to the top of the retarder, where, due to the heat caused by the rubbing of the journal against the retarder, the grease is melted and flows over the back and through the holes onto the journal.

A very satisfactory retarder can be made from babbitt metal, as follows: The metal is cast in the form of a grid, bent to conform to the surface of the journal. The bottom surfaces of the cross-bars are grooved in the direction of rotation of the journal, to aid in the distribution of the lubricant. The cross-bars are also rounded off on the edge towards the direction of rotation, for the same reason that it is best to round off the edge of any oil groove. This allows the resulting wedge that is formed to aid in the reduction of the scraping action between the retarder and the journal.

SPECIAL GREASE PRODUCTS.—Wool yarn is sometimes mixed with a No. 3 cup grease to produce a lubricating product that will stay put and be retarded from permitting the grease constituent to escape too freely from an open bearing. Horse hair is also mixed with grease for the same purpose and also to make a lubricating mass that is resilient and tends to lie close to the journal.

SECTION 8

LUBRICATING AND INDUSTRIAL OIL EQUIPMENT

FILTERS, FILTERING AND RECLAMATION

FILTERS AND FILTRATION

THREE METHODS OF FILTERING LUBRICATING OILS.—There are three methods of filtering lubricating oils that are in general use; namely, capillary, pressure and gravity filtration.

FILTERING OPERATIONS.—There are two distinct operations to be performed during the filtering operation; namely, (*a*) the elimination of dirt and other impurities, and (*b*) the separation of any water that may have become mixed with the oil.

REQUIREMENTS OF AN EFFICIENT FILTER.—The following general specifications should be used as a guide in the selection of a filter:

(*a*) The filter should have large settling or precipitation capacity.

(*b*) The filtering medium should be easily and cheaply renewed.

(*c*) There should be sufficient area of the filtering medium exposed to the oil.

(*d*) A strainer should be provided to strain the incoming dirty oil.

(*e*) The path of the oil through the filter should be as long as possible.

(*f*) The entire area of the filtering medium should be subjected to as nearly as possible, an even pressure of oil.

(*g*) All handles and cocks of the filter should be well nickeled or other provision made for the prevention of rust.

(*h*) The body of the filter should be constructed of heavy-gauged metal.

FILTERING MEDIUMS.—There are a number of materials used for filtering mediums. The primary requirements of an efficient filtering medium may be enumerated as follows:

(*a*) It should be easily removed for renewal.

(*b*) It should be easily cleaned, to allow for frequent replacement and cheap upkeep cost.

(*c*) It must not be too dense, or it will unduly retard or interfere with the flow of the oil through the filter.

(*d*) It should possess long life.

(*e*) It should filter efficiently.

The filtering mediums usually met with in general use are charcoal, animal bone dust, waste, asbestos, sacking and a specially-made filtering cloth.

By far the best and most serviceable filtering medium is cloth. Cloth does not offer too great a resistance to the flow of the oil. It can be easily cleaned, and any desired thickness can be obtained by using various numbers of layers.

Dense substances, such as charcoal, bone dust, etc., offer too great a resistance to the flow of the oil and produce extremely slow results. The

removal of this dense type of filtering material is a tedious and difficult task, and requires that the filtering operation be stopped during the time of renewal of the filtering medium. Filter cloths can be easily and quickly replaced when necessary, without disturbing the continuous flow of the oil through the system.

EXCELSIOR is sometimes found in use as a filtering medium in filters that are supposedly in the hands of experienced operating engineers. It is, however, one of the most unsuitable substances possible to obtain for this purpose, because, when oil is warm, it will absorb resin from the excelsior and soon will become thickened with a brownish mass, which will appear on the strainer cloths or sieves.

FILTERING CLOTHS.—This cloth can be obtained in various textures to meet each condition of service, and by means of the ingenious methods adopted by the filter manufacturers a maximum " filtering area " can be obtained.

Dirty cloths removed from the filter may be washed and kept ready for instant replacement in the filter as occasion requires.

PROCESS OF FILTERING.—The operation of a typical, efficient filter may be briefly described as follows:

(*a*) The incoming oil containing impurities, such as water, dirt, metallic chips, etc., is first strained through a wire sieve or cloth strainer.

(*b*) It is then passed into the heating compartment. Here its gravity is reduced and the thinned oil is less able to retain water and solid matter. Usually steam is used to heat the oil, being carried through the compartment in a coil.

(*c*) Next, due time is given to allow the water and solids to be freed from the oil by passing it slowly over precipitation trays, or by other methods.

(*d*) The oil is then passed through the filtering medium to the clean oil compartment.

GRAVITY FILTERING.—Fig. 1, Sec. 8, shows a type of gravity filter as manufactured by the Pittsburgh Gauge and Supply Company, of Pittsburgh, Pa.

The operation of this type of filter may be described as follows: The dirty oil enters through the screen *B* into the settling tank *A*, and is then passed through the valve *C* into the funnel *D* and into the central compartment. The funnel *D* is provided with a screen, and at the lower end with a perforated conical foot *E*, closed at the bottom.

The central chamber is partially filled with water and is kept at a moderate temperature by the steam coil *I*. The dirty oil descends through the funnel tube and is discharged below the surface of the water at the foot of the tube.

When the level of the oil reaches the outlets *J*, *J*, it flows through into the filtering cylinders *K*, *K*, formed of open-wire mesh and wrapped with several layers of filtering cloth. Passing through this filtering medium, it is then collected in the main storage tanks *L* and is ready for use.

Fig. 2, Sec. 8, shows a gravity filter manufactured by The S. F. Bowser & Co., Inc., of Fort Wayne, Ind.

The flow of oil in this type of filter is indicated by the directing arrows in the figure. This type of filter makes use of the precipitating tray principle, which is very efficient.

Fig. 3, Sec. 8, shows an isometric view of a Peterson Power Plant Oil Filter. The filtering and purifying operation of this filter may be described as follows: The dirty oil is put into the filter through the strainer box 1, and passes down through the strainer 2, which is designed to remove any large particles of waste that may be in the oil. The oil is

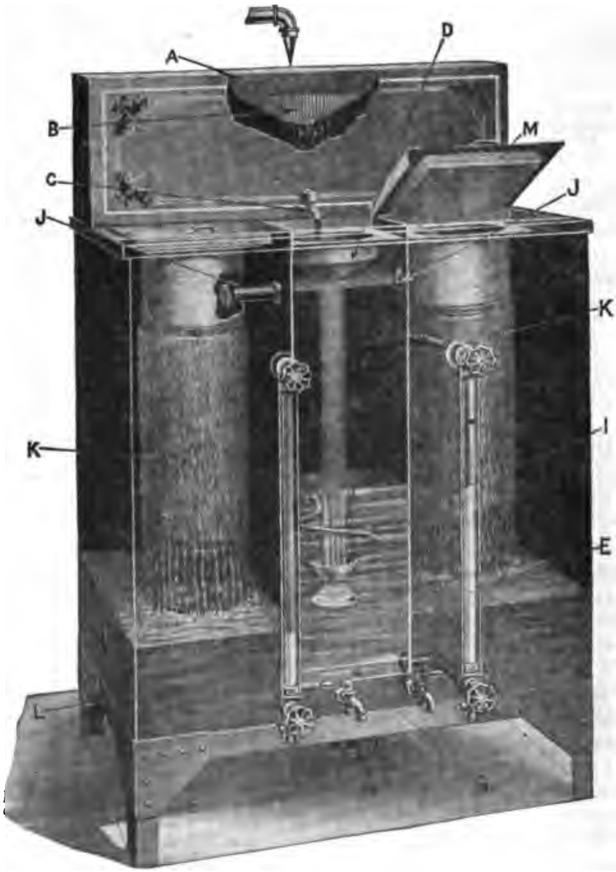


FIG. 1. SEC. 8.—Gravity oil filter.

then passed to the warming tray 3, which contains the heating coil 4, and then passes consecutively through the compartment 5, funnel 6, pipe 7, and over the baffle 8 (see Fig. 4, Sec. 8), under the bottom tray 9.

The oil is then passed in a zigzag course upward over the trays 9, 10, 11 and 12, and out through the opening 14 to the filtering compartment. (The rated capacity of the oil in passing over the trays is 0.7 foot

FIG. 2. SEC. 8.—Gravity oil filter.

per minute, and the manufacturers claim that the slow passage of the oil greatly increases the settling efficiency of the filter.) The separated water is drawn off from the trays by the funnels 15, 16, 17 and 18.

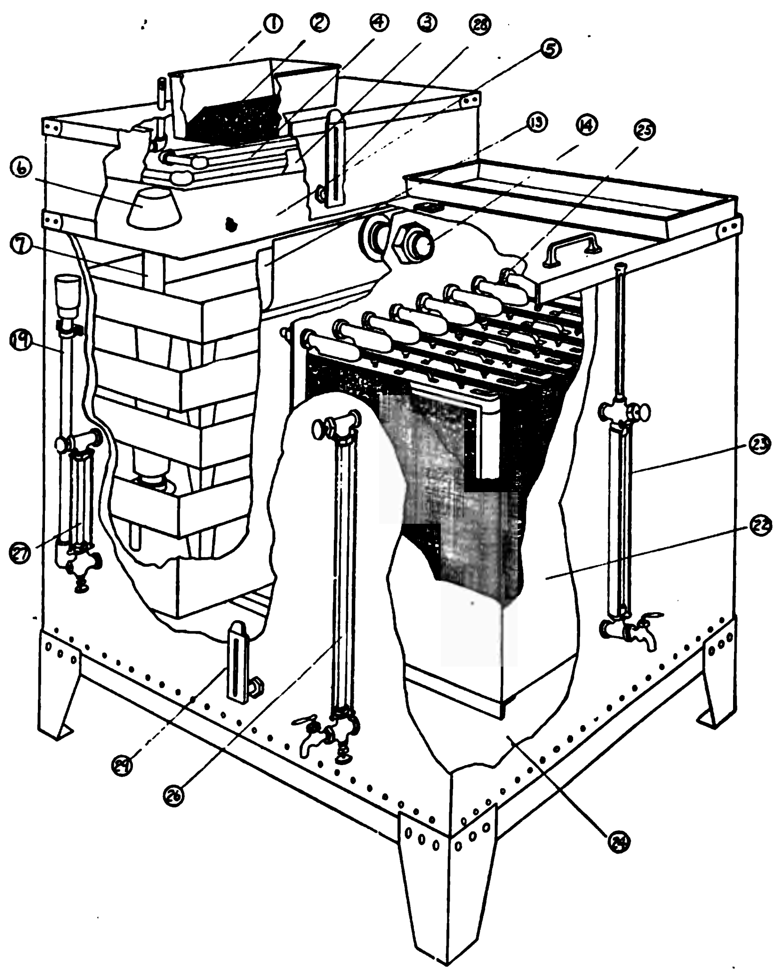


FIG. 3. SEC. 8.—Peterson power plant filter, showing interior construction.

The filtering compartment contains a number of filtering units, which are made of heavy galvanized screen wire, the sides being separated one inch and covered by a bag-shaped filtering cloth that is slipped over each unit.

The oil passes from the outside to the inside of the filtering units, then out through the nozzles 25 into the clean oil department.

FILTER NOTES.—Some filters are in use which depend upon the capillary action of the filtering medium. The oil is siphoned from the dirty oil compartment to the clean oil compartment by the use of wicking. The dirt and impurities which may be in the oil are intended to be left in the wicking.

Generally, oil filters are equipped with steam pipes, so that the body of the oil may be reduced in order to facilitate precipitation of the impurities held in suspension in it. The steam supplied to this coil should never

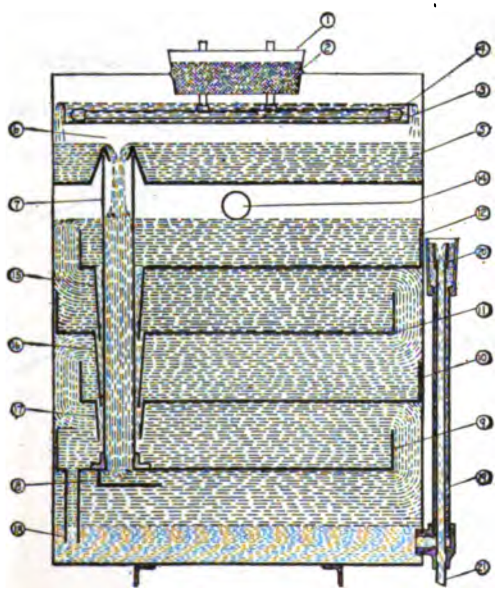


FIG. 4. SEC. 8.—Section through the precipitation compartment of a Peterson power plant filter.

be taken from live steam mains, for, while good results can be obtained by moderately heating the oil to a temperature of 130° to 150° Fahr. with exhaust steam, excessive heating will tend to destroy the lubricating qualities of the oil.

THE CARE OF FILTERS.—Careful attention must be paid to the systematic and frequent cleaning of oil filters. Especially is this true for filters used in continuous oiling systems.

When the dirty filter medium is removed from the filter, the sediment at the base of the filter must be removed. Many careless "oilers" allow this sediment to collect for some time, and so long as it is held largely in suspension between the water and oil layers it increases rapidly and will soon work up into the oil and cause poor filtering results.

Sudden hot bearings, occurring at several points in the engine-room, should always immediately result in an examination of the filter.

***FILTERING FACTOR OF SAFETY.**—The factor of safety for the capacity of the filter should always be considered when purchasing or specifying a new filter for use in a circulating system. Under-capacity of the filter is the cause of many hot bearings, which are unjustly blamed upon the circulating system as a whole or upon the oil used.

For large bearings, running at medium speeds, allow 4 to 5 gallons of oil per square foot of projected bearing area.

Usually about 2 1/2 to 3 1/2 gallons of filtering capacity per hour for each 100 H. P. for simple engines up to 175 R. P. M. will be sufficient. For compound engines 4 1/4 to 4 3/4 gallons per hour for each 100 H. P. will give a satisfactory capacity for the oil filter.

Tandem engines should be rated as outlined above for simple engines, with the result multiplied by 2.

For engines running above 175 R. P. M., the capacities as indicated above should be increased by about 25 per cent.

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* NOTE. Also see index.

SPECIAL FILTERING SYSTEMS

DRY SYSTEM OIL PURIFIER.—Fig. 5, Sec. 8, shows the outline of the Robertson dry-system oil purifier. In this filter no waste, excelsior, charcoal, paper or other ingredients are used. The impurities are precipitated entirely by heat. The oil passes through a strainer, where the heavier impurities are deposited. It then passes down through a pipe, almost to the bottom of the settling chamber, and while doing so it is heat treated and does not come into contact with the partly purified oil

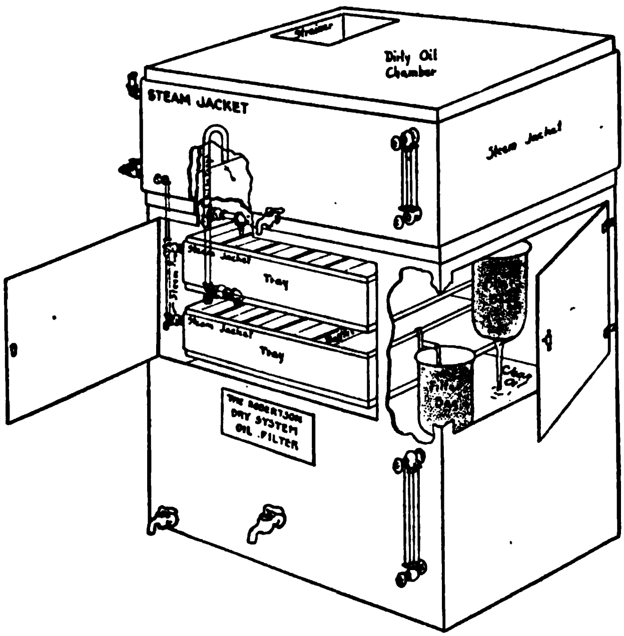


FIG. 5. SEC. 8.—Dry system oil purifier. Vertical type.

at the top of the settling chamber until the sediment and condensation are deposited at the bottom. The lighter oil rises and passes into a pipe leading to trays, each branch of which is fitted with a valve regulating the flow of the oil. Each tray has a separate steam-jacket surrounding it. The oil receives a separate heat treatment in each tray and flows in a baffled course until it reaches the filter bags, where such substances as mica and graphite are removed. After this it flows into the clean oil compartment.

PRESSURE OIL FILTERS.—The pressure system of oil filtering must not be confused with that of the gravity system. In the pressure system, direct pressure is used. This pressure is created by compressed

air, city water pressure or by means of a pump. The filters are operated with pressures up to 100 pounds per square inch.

A sectional view of the Anderson pressure oil filter, made by The V. D. Anderson Company, is shown in Fig. 6, Sec. 8. Its operation may be detailed as follows:

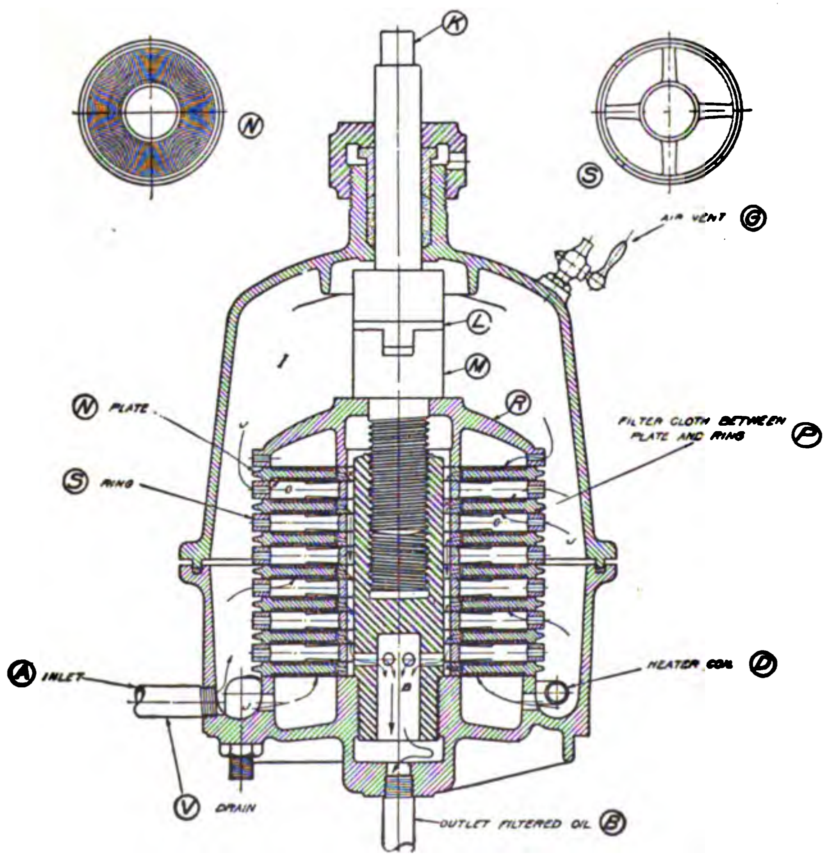


FIG. 6. SEC. 8.—Pressure oil filter. Sectional view.

The oil to be filtered is pumped in at inlet *A*, filling the space *I*. It then passes through the opening *J*, in the spacing rings *S*, where it comes into contact with the filtering medium *P*. This filtering medium is clamped between the rings *S* and plates *N*.

The pressure forces the oil through the filtering medium into the grooves and channels on the faces of the corrugated plates *N*, where it is led to the openings *X* and passes down and out at the outlet *B*.

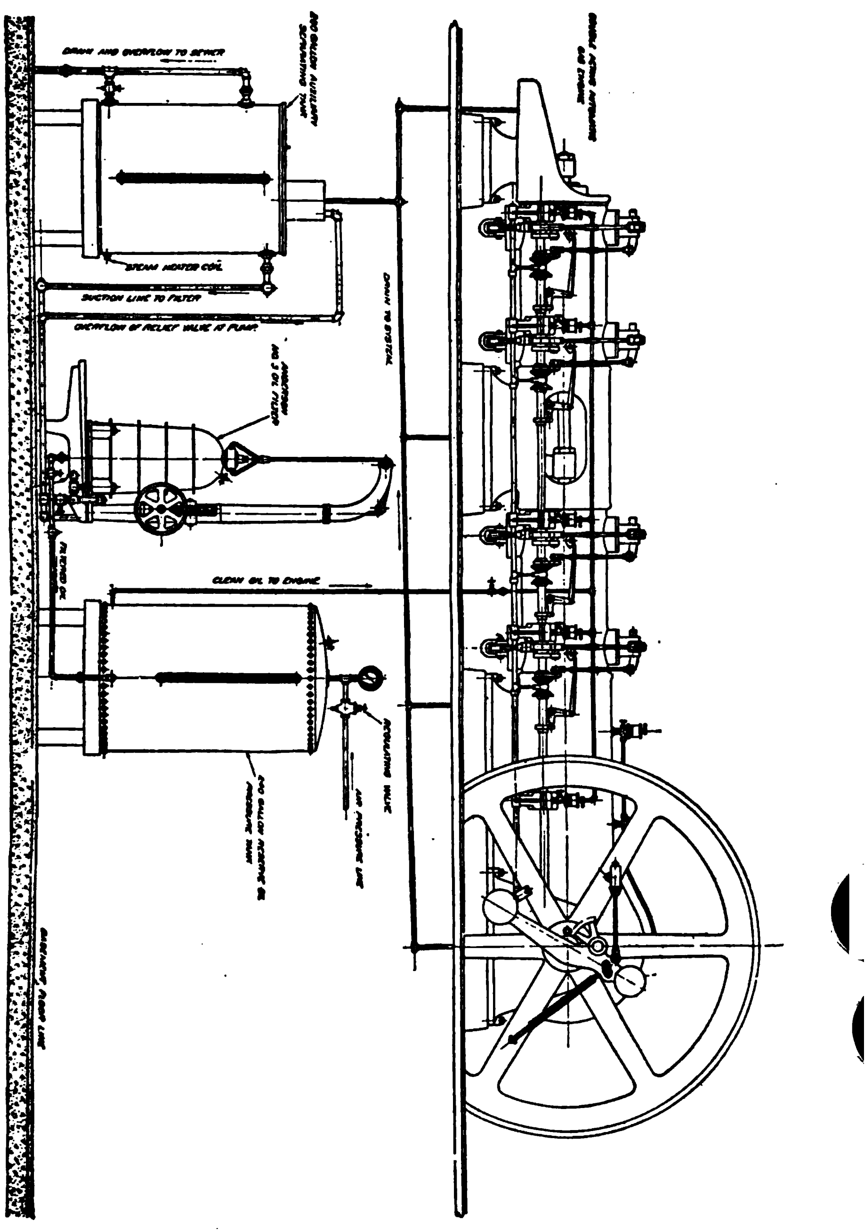


FIG. 7. SEC. 8.—Pressure oil filter using air pressure. Shows complete system.

When it is necessary to filter a large number of batches frequently, a continuous type of system should be used. A typical installation for this type of system to handle would be four machines of the same size. In this case, the oil for each machine could be changed once a month, giving each machine one week for clarifying its oils. A continuous system, to handle the same work, would necessarily be very large, and require a large quantity of oil.

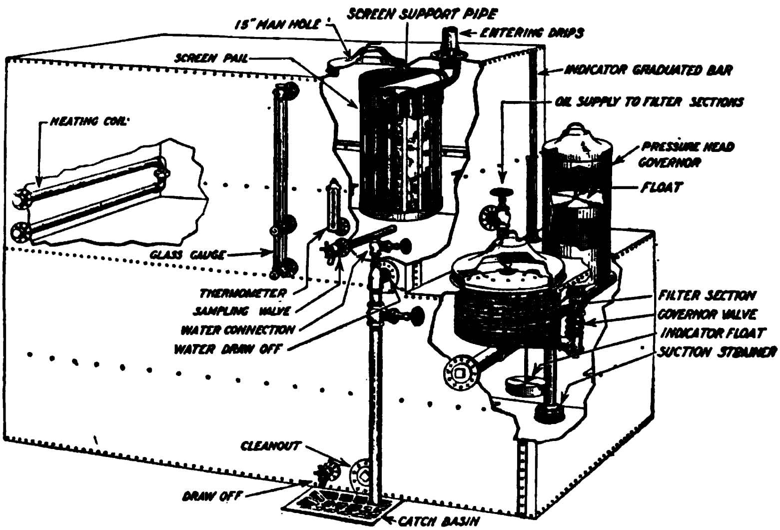


FIG. 9. SEC. 8.—Sectional view Batch filtration system.

Fig. 9, Sec. 8, shows a sectional view of the system shown in Fig. 8, Sec. 8. The operation is as follows.

1. Dirty oil to screen in pail.
2. To upper precipitating chamber to settle water.
3. Slowly passed to filter section.
4. Automatic governor keeps flow of oil constant.

ELIMINATION OF OIL AND AIR FROM FEED WATER ELECTRICALLY.—(De Ingenieur, Nov. 9, 1918.) In a paper read by J. C. Dijxhoom, of the Royal Institution of Dutch Engineers; abstracted through the *Journal of the American Society of Mechanical Engineers:* "The presence of cylinder oil in boiler feed water is likely to cause trouble. * * * Numerous devices resorted to to overcome this trouble are: Trays with porous material, through which the water can move backward and forward, while the oil is deposited on the material; coke filters, where the oil adheres to the surface of the coke; pressure filters, where the water is forced through filter cloths, which (are expected to) retain the oil." * * *

These devices are not successful because "the oil is in an emulsified state and divided into globules of less than 0.001 mm. diameter, which can pass through the finest filtering medium. * * * The tiny globules can be made to coalesce by passing an electric current through the water, * * * using continuous current at 110 volts while the water flows through the feed pipe. The electrically treated water is then sent through a pressure filter, consisting of perforated cylinders covered with cloth and enclosed in a strong vessel, provided with inlet and outlet valves. Such a filter has little effect upon ordinary feed water, but as the electric process described above causes the oil globules to coalesce, the whole of the oil is effectively retained, leaving pure water only to pass through. * * * A pressure gauge on the filter indicates the condition of the filter cloth, which must be changed when the pressure rises much above boiler pressure." * * *

De Ingenieur (November 30, 1918; abstracted through the *Journal of the American Society of Mechanical Engineers*) describes an oil recovery plant used at the Central Station at Flushing: "It is similar to the Perret plant used in England for the last 15 or 20 years. The feed water is first allowed to flow through a brickwork tank, having baffle plates, with openings at the bottom, while the oil which rises between the plates is removed through a valve, and freed from water and dirt by passing it through a centrifugal separator. The feed water is then conducted to a second tank fitted with metallic baffle plates charged with continuous electrical current at a pressure of 8 volts. Emulsified oil again separates as a layer between the plates, and can be recovered as before. The feed water is finally passed through a coarse filter, which removes the last traces of the oil." (Technical Supplement to the Review of the Foreign Press, London, Vol. 3, No. 3, January 21, 1919, No. 3905, p. 41.)

RECLAMATION PROCESSES

MOTOR OIL PURIFIER.—Lubricating oil which is removed from the crank-case of internal-combustion engines usually contains a considerable percentage of free carbon in suspension, dirt and grit, and possibly some water. Generally, the oil removed from the crank-case of gasoline- or kerosene-burning engines will also be found to be contaminated and reduced in viscosity, due to some of the heavy ends of gasoline or kerosene, which have leaked past the piston rings and mixed with the oil. Recent tests have indicated that if these impurities are entirely removed and the viscosity of the oil brought back to its original viscosity, the oil thus reclaimed can be again used in the engine from which it was taken with satisfactory results. The process of reclaiming used oil of this type really involves a " re-refining " for removing the carbon-forming element.

The motor oil purifier, as made by the Richardson-Phenix Company, is designed for the purpose of reclaiming used motor oil, and consists of two concentric shells. The oil to be purified is contained in the inner shell, and the outer shell provides a water-jacket. A hood covers the purifying tank, for the purpose of preventing the fumes driven off from the oil during the process of reclamation from spreading, and several lengths of pipe are connected to the hold for carrying away these fumes.

The following instructions and description of operation are given by the manufacturers, describing the method of installation and operation of the Richardson-Phenix motor oil purifier. (See index for data pertaining to reclaimed oils as motor cylinder lubricants.)

The Richardson-Phenix motor oil purifier consists of two concentric shells, the inner one containing the oil to be purified and the outer one a water-jacket; a hood covering the purifier tank, thus preventing the fumes driven off from the oil during the process of reclamation from spreading, and several lengths of pipe connected to the hood for carrying the fumes away.

At one place the inner shell is attached directly to the outer shell. allowing space for connections from the outside of the purifier to the inner tank. The purifier is shipped with all piping in place. After uncrating, and the hood has been put in place, the apparatus is ready to be connected to the steam, water and sewer lines.

Installation

Referring to Fig. 10, Sec. 8, a live steam line is connected to 3/4-inch elbow 1. The steam pressure should not exceed 30 pounds gauge pressure. If the pressure is higher than this, a positive pressure-reducing valve must be placed on the steam line. A shut-off valve must be placed on the steam line so that purifier can be disconnected and removed if necessary.

A 3/4-inch cold water line is run to 2. A shut-off valve should also be placed on this line.

A 1 1/2-inch sewer connection is run to sludge draw-off 3. A shut-off valve placed in this line is closed during the process of purification, to prevent oil draining from inner compartment to sewer.

At point 5 of water overflow a 1-inch connection to sewer is made,

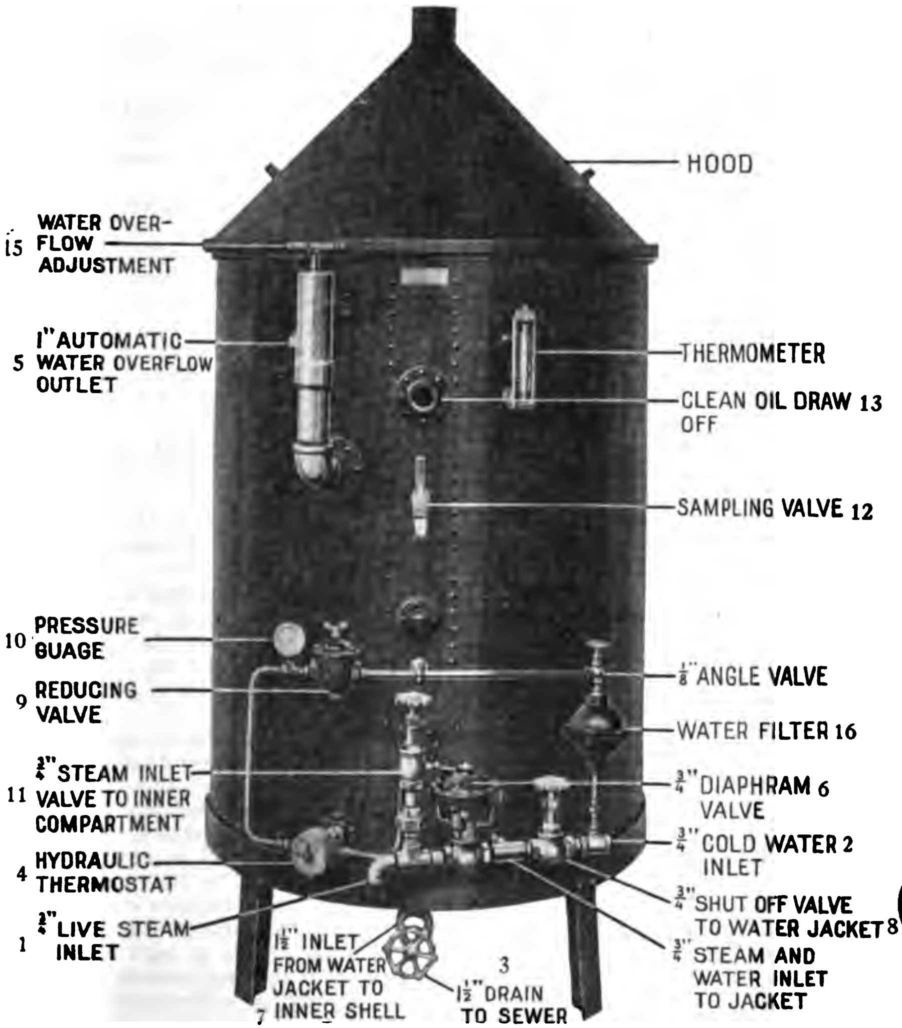


FIG. 10. SEC. 8.—Motor oil purifier.

allowing the overflow water to escape during the drawing off of the reclaimed oil.

The drip from thermostat catch funnel 4 is carried off by a drain connection into the drain line from the water overflow to the sewer.

NOTE. For the operation of purifier for the reclamation of oils used in producer or natural gas and crude oil burning engines see special instructions.

Operation—For Used Gasoline Motor Oils

The valve on sludge line 3 to sewer is closed.

The pointer on thermostat 4 is turned to "cold" position. This keeps diaphragm valve 6 closed.

Valve 7 controlling the connection between water-jacket and inner compartment is closed.

Open valve on cold water line to point 2 and shut valve 8, which controls the flow of fresh water into water-jacket.

Set pressure-reducing valve 9 so that approximately 25 pounds pressure registers on pressure gauge 10.

Now open valve 8. This allows water to flow into water-jacket. When water-jacket is filled to within 4 inches of top close valve 8. The exact height of water to be maintained in water-jacket can be determined later.

Remove the overflow funnel at top of inner compartment. This is done so that funnel will not become covered with dirty oil while purifier is being filled. Put pipe cap on funnel nipple so that dirty oil does not splash into oil draw-off piping during agitation.

Pour or pump 125 gallons of dirty oil into inner compartment of purifier. The quantity of oil is shown by contents indicator, which is graduated in gallons and hung in inner compartment.

Now turn on live steam to purifier. Slowly open valve 11, which admits live steam through a perforated pipe in the bottom of inner compartment, to the dirty oil in it. As the oil warms up the steam valve is opened wide until the batch of oil is violently agitated. Be sure the steam pressure does not exceed 30 pounds, otherwise oil is liable to be blown out of purifier. During agitation the hood should be in place, to prevent fumes, driven off from the oil, from spreading. If the used oil contains more than 10 per cent. gasoline, this can be profitably reclaimed by condensing the fumes driven off during agitation of the oil.

The length of time necessary to agitate the oil with steam depends entirely upon the brand of oil, the amount of dirt and volume of gasoline or kerosene in it. If the oil contains a large percentage of gasoline or kerosene, it will have to be steamed much longer than if the percentage is low. The duration of steam agitation of the oil must be determined by actual experiment. Samples of oil can be drawn off at any time through sample valve 12 and subjected to a flash test. The flash-point is determined by slowly heating a given sample of oil in an open cup and noting the temperature at which a flame applied to the vapor will ignite it.

When the flash-point of the sample has been brought as high as the flash-point of the same oil when new, it is evident that the steaming has been carried on long enough to drive off the gasoline or kerosene ends. The maximum time generally found necessary for the steaming of an oil containing gasoline is one hour. In rare cases when the gasoline or kerosene used in an engine has a high end point, it may be necessary to finish the steam agitation of the oil at a higher pressure than 30 pounds.

After steam agitation of the oil has been completed, 1/4 pound of soda ash for each gallon of oil to be treated should be thoroughly dissolved in sufficient water to obtain a saturated solution, and the solution mixed with the oil. The function of the soda is to coagulate the carbon and other suspended impurities in the oil. It would be well to start with

1/4 pound of soda per gallon of oil and to reduce the quantity on succeeding batches until the right amount for each condition is determined. An excess of soda does no harm, therefore, it is not necessary to reduce the quantity too low.

It is not necessary to add water to used motor oils when being purified. Sufficient water is naturally added by steam condensation during agitation and with the soda solution. About three buckets of water are

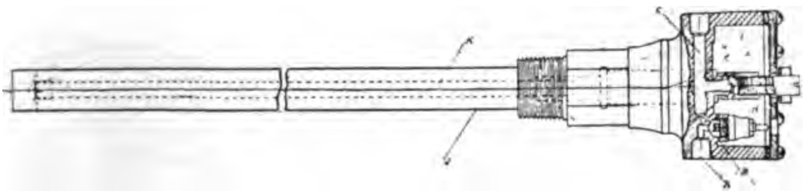


FIG. 11. SEC. 8.—Thermostat.

necessary to obtain a saturated solution of the amount of soda necessary for 125 gallons of oil.

After adding the soda solution, again agitate the mixture by steam in the manner described. The second agitation is carried on for about 15 minutes to assure a thorough intimate mixture of the soda solution with the oil. The success of purifier depends largely on the thoroughness of agitation.

After the second agitation close valve 11, thus shutting off the steam from the inner compartment of purifier.

Set the pointer on thermostat 4 to hot. This allows diaphragm valve 6 to open, thus admitting steam into the water-jacket. When the temperature of water-jacket has reached 180° set pointer on thermostat so that this temperature is maintained. The thermostat is extremely sensitive and when properly adjusted will maintain diaphragm valve 6 on a balance so that it will hold the jacket water within a few degrees of desired temperature.

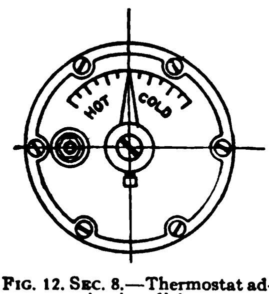


FIG. 12. SEC. 8.—Thermostat adjusting dial.

Operation of Thermostat

Cold water enters thermostat, Fig. 11, Sec. 8, at *A*, passes through adjusting pin valve *B* into passages *C*, *D* and *F*. Passages *C* and *D* lead to diaphragm valve 6, which is operated by the thermostat, and passage *F* leads past valve *H*, to exhaust port *G*, which discharges into catch funnel under the thermostat. Valve *H* is operated by the thermostat tube *J* and glass rod *K*. As *J* expands on rising temperature, it pulls rod *K* to the left, causing *H* to close. Water passing through *B* will accumulate in *C*, *D* and the diaphragm on the valve, causing diaphragm valve to close. When the temperature falls, *J* contracts, pushing rod *K* to the right, opening *H*, and exhausting the water in *C*, *D* and the diaphragm on the valve faster than the water enters at *B*, with the result that the diaphragm valve will open.

Adjustment

The thermostat is adjusted by means of screw *I*, Fig. 11, Sec. 8. Turning *I* to the right sets the thermostat at a lower temperature and to the left at a higher temperature. Fig. 12, Sec. 8, shows the adjusting dial and pointer attached to *I*, also the clock key adjustable pin valve *B*. The thermostat is set at the factory at approximately 150° when the pointer is in the position shown in Fig. 12, Sec. 8.

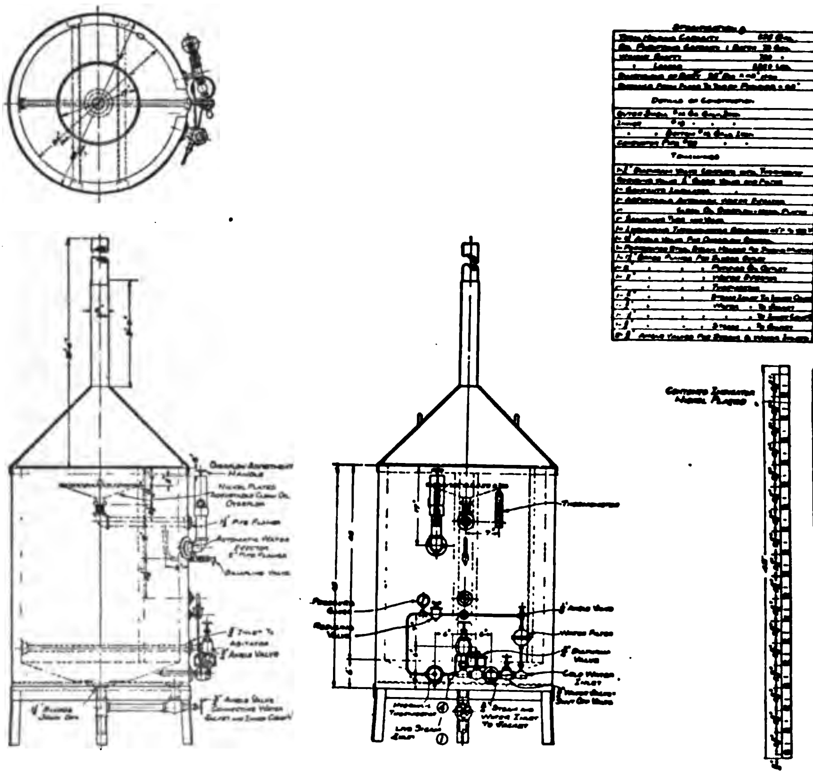


FIG. 13. SEC. 8.—Elevation motor oil purifier.

The oil is now allowed to settle. Usually about 10 hours' settling is sufficient. During the settling process it is not necessary to carry more than 5 pounds pressure on steam line. The steam valve in line to elbow is only cracked, especially if 30 pounds steam pressure is being used. This will throttle the inlet and reduce the pressure on diaphragm valve 6, making it somewhat more responsive to action of diaphragm.

Sampling tube 12 passes through a lock nut and has a 12-inch length of pipe inside of inner compartment of purifier. It can be swung to any position, permitting drawing off for test samples of oil from different

levels. By taking occasional samples the degree of settling can be ascertained by heating these samples to about 212° F. If moisture is present the familiar cracking and foaming will take place. Allow the batch to settle until all moisture settles out. By running a sample over a bright piece of tin or mirror, or by diluting it with 4 or 5 times its volume of gasoline, any particles of carbon still in the oil can be seen. The rate of precipitation of moisture and sludge depends to some extent upon the kind of oil being treated, so the length of time allowed for settling will have to be determined by experiment. It is advisable to let the oil settle as long as possible. This insures best results.

After settling process has been completed, the mixture in inner compartment is divided into three layers. At the bottom is a layer of water; above this is a layer of sludge. On top is clean oil.

Removal of Clean Oil

The clean oil is removed from purifier by displacing it with water. It should be drawn off at a temperature not less than 120° F.

Remove pipe cap from overflow funnel nipple in inner compartment, and replace funnel.

Open valve 7, which connects inner compartment containing reclaimed oil with water-jacket. This valve should be *slowly* opened, so that water does not rush from water-jacket into inner compartment, thus agitating the sludge and allowing it to mix with the clean oil again.

Now slowly open valve 8, admitting additional water to water-jacket. This water gradually displaces the oil in inner compartment, so that it will rise up and flow into clean oil overflow funnel, thence out through 1 1/2-inch connection 13.

Return the first purified oil drawn off to your dirty oil storage reservoir, to be sure that the clean oil draw-off piping is thoroughly flushed of any dirt that may be in it.

The purified oil may now be allowed to flow into your clean oil storage tank.

Water Overflow Adjustment

The column of oil, sludge and water in the inner compartment and the column of water in the water-jacket form a U-tube, the columns of which are always in hydrostatic balance when valve 7 is open. Inasmuch as oil has a lower specific gravity than water, and, therefore, weighs less, the height of column of water in water-jacket will be somewhat lower than height of water, sludge and oil in inner compartment, especially when the latter is nearly filled with oil. As the oil is displaced, the column in the inner compartment is continually being made up of a greater proportion of water and less of oil, so that as clean oil runs off, the columns of liquid in inner compartment and water-jacket will more nearly approach the same height.

The water overflow 5 is provided as a check to prevent displacing too much oil and thus allow the sludge to follow over. The water overflow is equipped with a nipple having a running thread, which is adjustable by handle 15. After a little experimenting, the height of this nipple can be so adjusted that by the time most of the clean oil has been displaced the two columns will be in such a hydrostatic balance that water will commence to flow over top of nipple and out through connection 5 of

overflow, so that if additional water is run into inner compartment of purifier it will pass out through overflow, and not force sludge over into clean oil overflow funnel. The overflow nipple should be so set that carelessness in displacing clean oil will not permit sludge to get into the oil. In other words, set it low enough so that the water will flow out through overflow before all of the oil is displaced.

In addition to the adjustment of water overflow, the height of oil overflow funnel is also adjustable so that if by the time water is flowing out through the water overflow there is still any appreciable depth of clean oil on top of the mixture in inner compartment, the oil funnel can be screwed down on its nipple, allowing more clean oil to overflow into the funnel. It is not advisable to try and get the last pint of clean oil off top of the sludge, because the surface of the sludge is always more or less irregular and contains pockets which hold clean oil.

Furthermore, due to the direction of the flow of the oil, the sludge around the lip of the oil overflow funnel is usually somewhat higher than at the sides of the purifier; that is, the sludge is bent up at this point. As soon as sludge appears at oil overflow funnel, shut valve leading to the clean oil tank, and close valves 8 and 7; then allow oil to settle again for about half an hour. This will allow the layer of sludge to settle level where it has been somewhat disturbed during the operation of displacing the oil. Now open valves 7 and 8 and allow remaining oil to drain off into the used oil storage tank. This last run will contain some sludge, and it should be poured back into the dirty oil tank.

Cleaning

After the clean oil has been run off, the valves 8 and 7 are closed and the valve in drain connection to sewer at bottom of purifier is opened, allowing water and sludge to drain off to the floor drain.

Do not allow sludge to pass to sewer; catch it in floor drain. If holes are not large enough to prevent sludge from passing through, a fine-mesh screen should be placed in the floor drain.

After draining out inner compartment of purifier, replace hood, open valve 11 and blow live steam into the inner compartment for a few minutes, which will sufficiently clean the inside. It is only necessary to wipe off inner compartment near the top, above oil line, as any dirt below will merely mix with the next batch of dirty oil and settle out.

Operation—For Producer, Natural Gas and Crude Oil Burning Engine Oils

After purifier is set up according to instructions under heading "Installation," valve in sludge drain line 3 to sewer is closed.

The pointer on thermostat 4 is turned to "cold" position. This keeps the diaphragm valve 6 closed.

Valve 7, controlling connection between water-jacket and inner compartment, is closed.

Open valve on cold water line to point 2 and shut valve 8, which controls the flow of fresh water into water-jacket.

Set pressure-reducing valve 9 so that approximately 25 pounds pressure registers on pressure gauge 10.

Valve 8 is opened. This allows water to flow into water-jacket.

When water-jacket is filled to within 4 inches of top, close valve 8. The exact height of water in water-jacket can be determined later, according to the water overflow adjustment.

Remove overflow funnel at top of inner compartment and put pipe cap on funnel nipple. This is done so that funnel will not become covered with dirty oil while purifier is being filled.

Pour or pump 75 gallons of oil to be purified into the inner compartment of purifier and an equal amount of *water*. The quantity of liquid in this tank is shown by contents indicator, which is graduated in gallons and hung in inner compartment.

From 1/2 to 1 pound of soda ash for each gallon of oil (not water) to be treated is thoroughly dissolved in sufficient water to obtain a saturated solution, and this solution poured into inner compartment. The function of the soda is to coagulate the carbon and other suspended impurities in the oil. It would be well to start with 1 pound of soda per gallon of oil (not water) and to reduce the quantity in succeeding batches until the right amount for your conditions is determined. An excess of soda does no harm, so do not try to reduce the quantity too low.

After the soda solution has been added to the oil and water, place hood on purifier and open valve 11 *slowly*. This admits steam through a perforated pipe into the mixture of oil, water and soda in inner compartment of purifier. As the mixture warms up the steam valve is opened wide until the mixture is violently agitated. The steam pressure must not exceed 30 pounds, otherwise some of the mixture is liable to be blown out of the purifier.

Allow the mixture to agitate for at least 15 minutes to assure a thorough intimate mixture of the oil, water and soda solution. The success of purifier depends largely upon the thoroughness of agitation.

NOTES ON OIL RECLAMATION.—In connection with the use of motor oil reclaimers, it has been found that a vegetable soap containing approximately 20 per cent. soda base, 70 per cent. sodium carbonate and 10 per cent. moisture can be used in place of straight soda ash for reclaiming used lubricating oils with the oil reclaimers, and oils so recovered have been found to equal in quality oils reclaimed with the use of straight soda ash. It is also said that where a badly emulsified oil, caused by imperfect refining, is to be reclaimed, treatment with the vegetable soap produces better results than with the soda ash treatment. Also, there is indicated a saving in time and expense of materials.

RECLAMATION OF MINERAL OIL CONTAINING A PERCENTAGE OF ANIMAL FATS.—A test covering reclamation of used motor oil, plus 5 per cent. of lard oil, was reported as follows: Fifty gallons used oil, plus 5 per cent. lard oil, used. Tests of used oil were:

Flash test: 225.
Fire test: 500.
Viscosity: 79 at 212.
Gravity: 27.5.

The oil was put in a reclaimer, steamed 2 hours with 30 pounds steam pressure, and allowed to settle 5 hours, while jacket water was held at 180°. At the end of this period the oil was badly emulsified. Sludge drawn off from bottom of reclaimer, 8 pounds of saturated salt water

added to bath and steam again introduced for a half hour. It was allowed to settle, with the water-jacket at 180°, which required 10 hours for the oil to settle clean. Thirty-eight gallons of clean oil were recovered, having the following tests: Flash-point, 410; fire test, 505; viscosity, 84 at 212; moisture, noticeable amount. * * * Fifty gallons of oil, same tests, steamed for 2 hours, carrying 30 pounds pressure on the boiler. Eight pounds soda ash added in solution; allowed to settle; jacket water at 180° F.; batch required 2 hours to settle clear, from which 42 gallons of clean oil of the following tests were recovered: Flash, 425; fire, 515; viscosity, 84.5 at 212; moisture, trace.

OPERATION NOTES, RECLAIMED OIL.—Tests are reported in connection with motor oil reclaimers operated on airplane motor oil and auto oil with the following results: The percentage of airplane motor oil reclaimed, as applied to oil reclaimers, 88.2 per cent.; percentage of auto oil reclaimed, as applied to oil reclaimers, 79.8 per cent. It is also reported that at a flying field, which started with 3000 gallons of dirty motor oil, basing the figures on a consumption of 20 per cent. by combustion and 15 per cent. by reclamation, it was found that the oil circulated 8 times before the original quantity was reduced to 200 gallons, when new oil was added, giving an efficiency of 294 per cent. Eight reclamations on the original oil raised its viscosity from 85 to 94 seconds at 212° F., and practical observation would indicate that oil can be used until by successive usage and reclamation it has all been consumed. A block test, made with reclaimed airplane engine oil, for a period of 6 hours on a new engine, indicated that the conditions of the engine at the completion of the test showed no perceptible difference between the results obtained with new oil and with reclaimed oil.

Samples of new and reclaimed oil, as obtained from four airplane engines, gave the following tests:

Engine No.	A Overhauled		B Run 50 hours		C New motor		D Overhauled	
	Unused	Used	Unused	Used	Unused	Used	Unused	Used
Time operated	203 min.		478 min.		435 min.		531 min.	
Viscosity of oil at 212	89	87	89	80	89	82	89	88
Viscosity of oil at 130	402	370	402	377	402	370	505	453
Flash	430	330	430	310	430	330	420	375
Fire	480	480	480	488	480	490	485	470

Other tests of new and used oils give the following results, illustrating the effect of reclamation:

Characteristics	Test A				Test B	
	New oil	Right motor	Middle motor	Left motor	New oil	Reclaimed oil
Gravity	26.2	26.6	26.8	26.5	21.7	21.5
Flash	455	435	420	435	400	390
Fire	520	530	530	525	470	460
Viscosity at 100	...	...	...	...	878	876
Viscosity at 130	...	...	...	...	...	322
Viscosity at 212	87	85	88	90	70	70

PURIFICATION AND RECLAMATION OF OILS, CENTRIFUGAL PROCESS.—Centrifugal force will separate substances of different specific gravities. Centrifugal separation takes places in the same manner as gravity separation, where liquids of different specific gravities, or solids mixed with liquids, have a tendency to separate. However, centrifugal separation depends upon a force much larger than that of gravity, and thus quicker separation may be obtained, and separation may be accomplished under more difficult conditions where gravity would fail or only partly accomplish this operation. The separation operation is often counteracted by the viscosity of the liquid, and is also affected by the slight difference in gravity of the substances to be separated and the fineness of the substance held in suspension. A comparison of centrifugal separation and gravity settling is shown in Fig. 14, Sec. 8, as given by the DeLaval Separator Company, Bulletin No. 100. In the samples illustrated, each bottle contained the same quantity of mixture of lubricating oil and water and a small amount of sand. The bottle on the left was allowed to stand for 24 hours undisturbed, and the bottle on the right was subjected to strong centrifugal action for one minute.

FIG. 14. SEC. 8.—Illustrating the relative results of gravity and centrifugal settling.

The reclamation of lubricating oils and purifying them has been used under a number of typical conditions, such as *with turbine-driven* units, for reduction gears and bearings, some of which may be cooled by water circulation, and the circulating oil may also be cooled in a separate cooler, where water circulation carries off the surplus heat of the oil, and some of this water may find its way into the oil system, due to various causes, such as leaks, etc., the sweating of oil storage tanks, or the leakage of steam past packing. Water, especially salt water, has a very detrimental effect, not only on the efficiency of lubrication, but also upon the metal parts.

Where engines are run condensing, the centrifugal process of separation may be used to remove the lubricating oil which passes with the steam into the condenser, so that both the water and oil can be re-used.

For gasoline motors, the dirty oil removed from the crank-case, which may contain gasoline, metallic particles, carbon particles and water, may also be treated by the centrifugal process, in which operation the oil is first treated by blowing live steam through it to remove the gasoline. The oil is then run through the centrifugal purifier.

The DeLaval Separator Company, manufacturers of the DeLaval Oil Purifier, state that in connection with the removal of colloidal carbon, after removing the gasoline by blowing live steam through it, as above described, a counter-colloid should be added to the oil, and the oil then passed through the centrifugal purifier.

This method is also used to remove oil from car-axle waste for railroads. While there have been methods for removing the oil from the

waste, the oil itself has not been satisfactorily reclaimed. The reclaimed oil can be treated by the centrifugal process, which consists of taking the oil and washing liquids, discharged by the waste-washing machine, and passing it through a so-called "clarifier," in which the solids are separated from the liquid (see later description of DeLaval Multiple Oil Clarifier) and then through an oil purifier (see later description of DeLaval Oil Purifier).

For the reclamation of cutting oils, which, after passing over the work and tools, carries with it metallic particles, dust, grit and some water, the centrifugal process may be used. The chips in the machine shop also carry away considerable quantities of oil adhering to them (see index for recovery of cutting oils). A method for recovering this oil is with the use of a centrifugal extractor, where steam comes into contact with the chips. The oil recovered by the centrifugal extractor can then be purified and reclaimed by use of the centrifugal purifier. The manufacturers state that in reclaiming cutting oils by this method the oil is sterilized.

FIG. 15. SEC. 8.—Sectional view of the De Laval multiple oil clarifier bowl.

The centrifugal process may also be used where oil and dirt have been removed from work by washing in a solution of hot soda ash or a similar solution, where the oil, mixed with the wash, as well as the wash itself, is recovered, both of which are in condition for re-use. In treating the oil and wash, the mixture from the soda kettle is heated, passed through a clarifier to remove the solid particles, and then through a purifier for separating the liquid oil from the liquid soda wash, when the soda wash is ready for re-use and the oil is again passed through a purifier to remove saponified material.

Oils which are used in drawing processes can be recovered as described for the soda wash and cutting oils by this process.

Heat-treating oils, used in tempering steel, which may become polluted and thickened by the formation of solid carbon and scale deposits, may be treated by the centrifugal process by passing the oil through a clarifier at intervals. In hardening steel, where the final reduction in temperature is obtained passing the steel into cool oil and then removing the oil by subsequently washing in a soda kettle, the centrifugal process may be used.

For fuel oils used in internal-combustion engines of the Diesel type, where the fuel is forced into the cylinder against high compression, and where the valves and other working parts may cause trouble if impurities are in the oil, such as pipe scale and dirt, a centrifugal purifier may be

used to remove this foreign matter. Where fuel oils are high in sulphur content during the combustion of the fuel in the cylinder, the sulphur oxidizes and forms sulphur-dioxide (SO_2), which unites with the water present to form sulphurous acid, which, in the presence of oxygen, becomes sulphuric acid, and may attack the walls and cylinder heads of engines. The oil may be dehydrated by the centrifugal process to reduce the possible formation of sulphuric acid to a minimum.

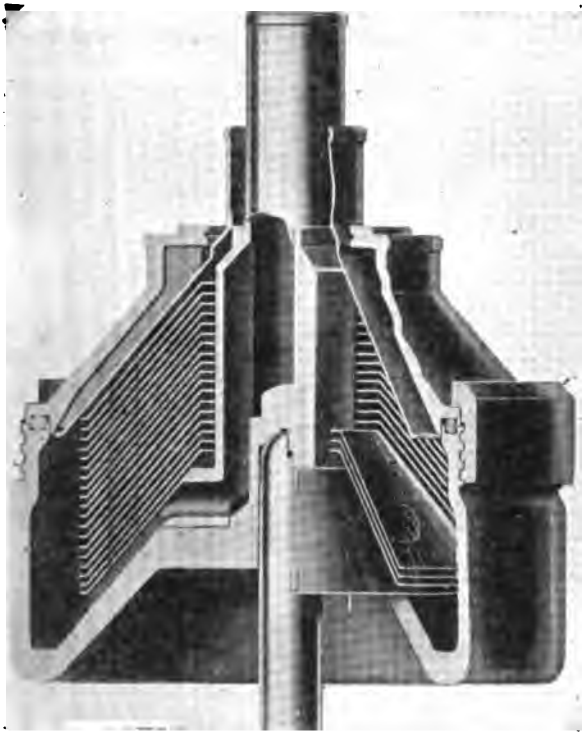


FIG. 16. SEC. 8.—Sectional view of De Laval oil purifier bowl.

Where fuel oil is used for heat-treating furnaces, forge furnaces, etc., as well as for furnaces in steam-generating plants, it is sometimes desirable where the percentage of water is high to remove it by the centrifugal dehydrator.

DeLAVAL CENTRIFUGAL OIL PURIFIER AND MULTIPLE OIL CLARIFIER.—The DeLaval Oil Purifier is designed to separate two liquids of different specific gravities and any sediment present in the liquid to remain in the bowl. The DeLaval Multiple Oil Clarifier is designed for separating solids from a liquid in which they may be suspended, discharging the liquid, while the solids are retained in sediment

pockets provided inside the revolving bowl. Fig. 15, Sec. 8, shows a sectional view of the DeLaval Multiple Oil Clarifier bowl. In operation, the oil is fed into the top of the bowl, and first enters the inner chamber, where the heavier and more easily separated solids are thrown out and held in the sediment pocket. The semi-clarified oil then passes into the second or outer chamber, where, by reason of the greater diameter, a maximum centrifugal force clarifies it of the finer and more difficult to remove particles, and the clarified oil is then forced upward to the discharge outlet. The manufacturers claim that with this construction the easier to remove impurities are taken out in a separate chamber so that when

G. 17. Sec. 8.—De Laval turbine-driven oil purifier.

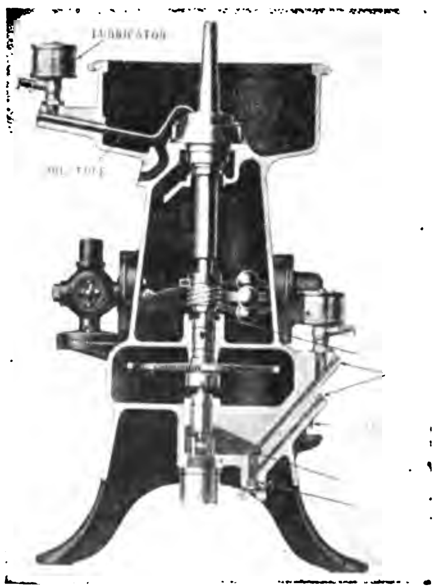


Fig. 18. Sec. 8.—Sectional view turbine-driven De Laval.

the partly-clarified fluid is subjected to the intense centrifugal action of the outer chamber the minute particles within the liquid are removed without interference from the heavier particles. They also claim another advantage in the large sediment-holding capacity of the double chamber, permitting long runs before cleaning becomes necessary.

Fig. 16, Sec. 8, shows a sectional view of the DeLaval Oil Purifier bowl. The oil to be purified is fed into the top of the bowl, and passes down the centre to the bottom, from which it flows out and up through holds in the disc and is distributed in thin layers between the discs. The manufacturers state that here, due to centrifugal action, separation takes place. The material heavier than water, such as sand and metallic particles, being thrown outward to the periphery of the bowl, and held there

in a sediment pocket by centrifugal force, and also the water, being heavier than the oil, passes outward and upward along the outer edge of the discs, and from there to the discharge outlet, while the oil, being lighter, passes inward between the discs, where the thin layers are subjected to tremendous centrifugal force, which throws out the remaining traces of impurities and water, the impurities being forced along the lower surface of each disc toward the sediment pocket and the pure oil being forced toward the centre shaft, and from there upward to the oil-discharge outlet.

Fig. 17, Sec. 8, shows a turbine-driven DeLaval Oil Purifier, having a capacity of 30 to 120 gallons per hour, depending upon the temperature and condition of the oil. Fig. 18, Sec. 8, shows a sectional view of a turbine-driven machine, and Fig. 19, Sec. 8, shows a sectional view of a belt-driven machine. The manufacturers state that the two main factors to be taken into consideration are maximum efficiency and maximum capacity of a given size of bowl when run at a given speed, and call attention to the fact that the smaller the diameter of the bowl the greater the speed at which it must be run to develop a certain centrifugal force, while the larger the bowl, in proportion to the amount of liquid to be run through it at a given speed, the higher will be the centrifugal force. Fig. 20, Sec. 8, shows a steam driving wheel (with a section of the rim cut away to show the steam impulse buckets) and the speed and steam pressure governing mechanism for a turbine-driven machine.

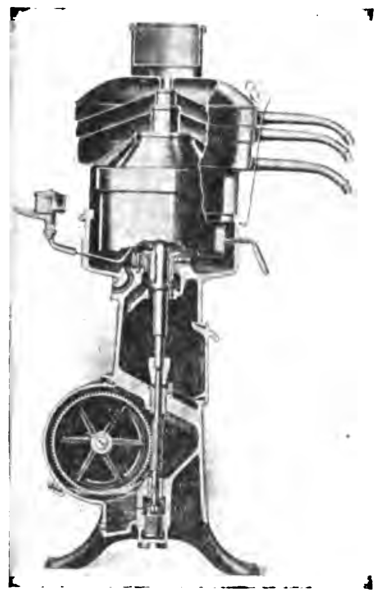


Fig. 19. Sec. 8.—Sectional view belt-driven machine.

Fig. 21, Sec. 8, shows piping diagram, embodying a DeLaval Oil Purifier, for purifying lubricating oil from direct connected turbines, using the pressure type of oil-feed system, and Fig. 22, Sec. 8, shows the piping diagram for direct-connected turbine using a gravity-feed oil system on a DeLaval Oil Purifier.

For geared marine turbines, where the gears, bearings and other parts are run in an oil bath, and where impurities such as water, metallic wear, pipe scale, core sand, etc., may find their way into the lubricating oil system, a purifier may be used. The manufacturers recommend that in the case of geared turbines, the oil purifiers be installed between the overhead supply tank and the drain tank so that oil can be passed from the overhead tank, through the purifier, to the drain tank, and the purifier can also be located so as to purify all or part of the oil. Fig. 23, Sec. 8, shows the general arrangement of an oiling system for a geared turbine (marine).

For the purifying and reclamation of crank-case oils removed from internal-combustion engines, the DeLaval Oil Purifier is applied in either of two ways; one is called the batch system, which consists of purifying and processing all or any portion of the content of the oiling system at fixed intervals, and involves clean oil being put into the crank-case to take the place of the dirty oil to be treated, and after being purified the reclaimed oil is pumped into the clean oil tank. The other system is a

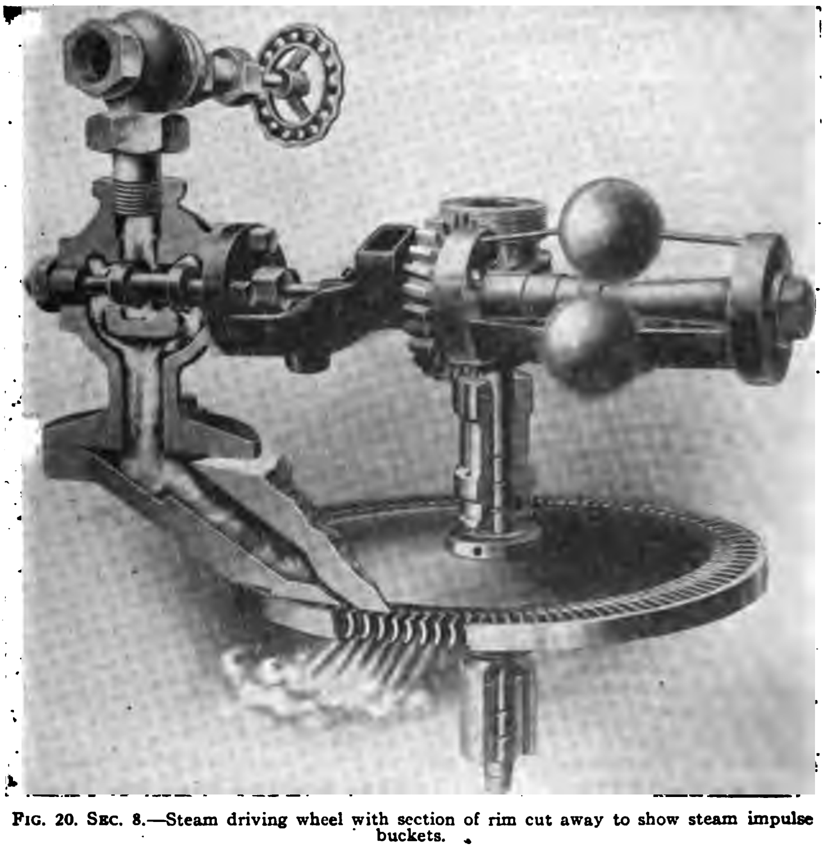


FIG. 20. SEC. 8.—Steam driving wheel with section of rim cut away to show steam impulse buckets.

continuous system, which consists of letting the oil run through the purifier at short intervals without processing, and it is pumped back into the crank-case directly from the purifier or into the clean oil tank, as desired. Fig. 24, Sec. 8, shows the general arrangement of the batch system with the DeLaval Oil Purifier, and also the arrangement of the continuous system of DeLaval oil purification, as applied to a Diesel engine. Where the crank-case oil contains gasoline, the method of installing the purifier is as shown in Fig. 25, Sec. 8.

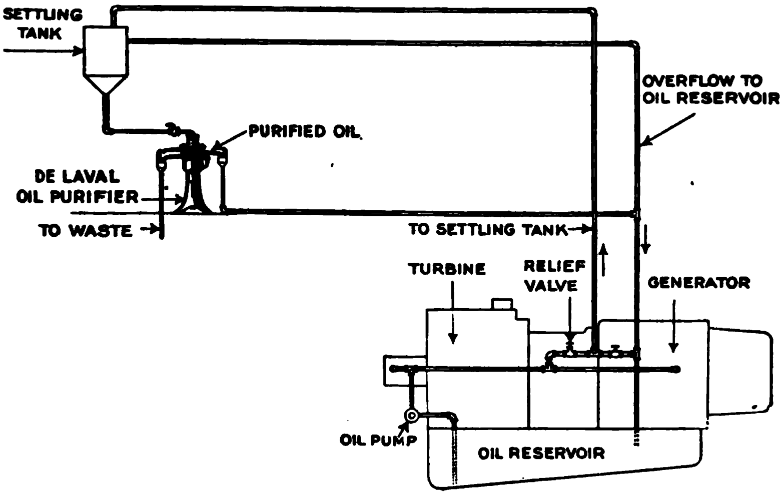


FIG. 21. SEC. 8.—The De Laval method of purifying lubricating oil from direct connecting turbines using pressure type oil feed system.

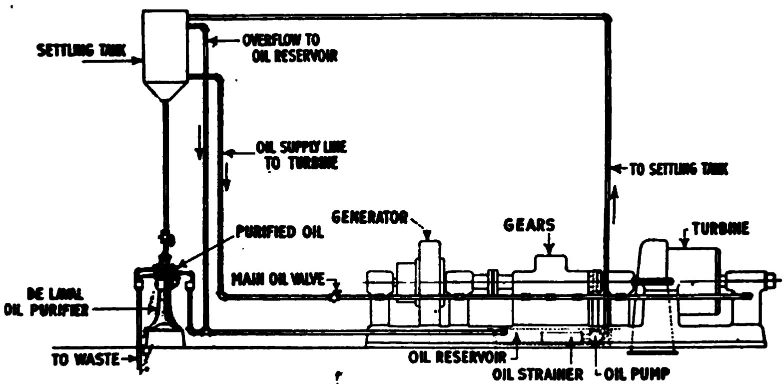


FIG. 22. SEC. 8.—The De Laval method of purifying lubricating oil from direct connecting turbines using gravity oil feed system.

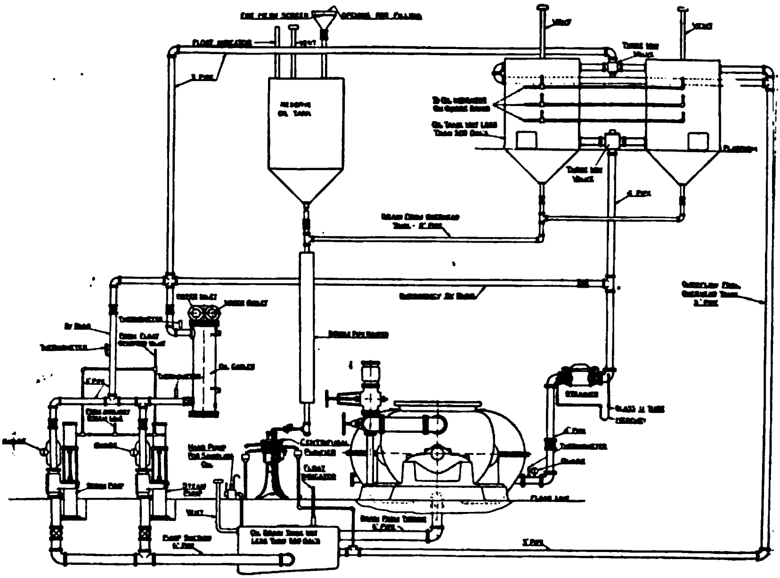


FIG. 23. SEC. 8.—De Laval oil purifier in oiling system for geared turbine (marine).

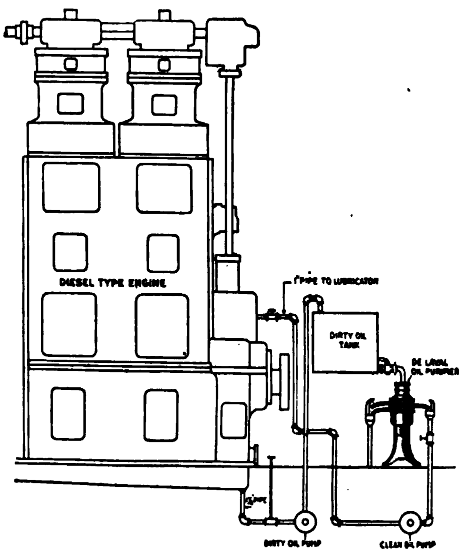


FIG. 24. SEC. 8.—General arrangement Batch and continuous system applied to Diesel engine, using De Laval system.

One of the advantages claimed for the centrifugal method of purification, with reference to marine installations, as compared to the gravity settling method and filtering system, is that these latter systems are

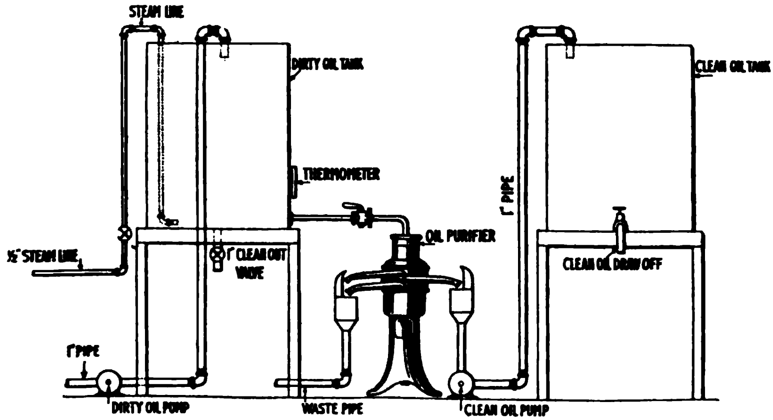


FIG. 25. SEC. 8.—General arrangement for purifying crank case oil (internal combustion engine), where oil contains gasoline.

affected by the motion of the ship, and that the centrifugal purifier will handle a larger quantity of oil, is positive in its action, is not affected by the motion of the ship and occupies only about two square feet of floor space.

The capacity of the oil purifier varies with the viscosity of the oil.

SECTION 8a

OIL COOLERS

There are a number of difficulties that surround the cooling of lubricating and other oils, since in oil coolers, as in the case of other heat-transfer apparatus, the fluid to be cooled must circulate and be cooled by contact with a metallic wall, which is maintained at a low temperature by flowing water or air.

The viscosity of oil increases with the reduction of its temperature, and there is a tendency towards a formation on the metallic walls of the cooling surfaces, of an oil layer, denser than the layers of oil which compose the main oil body. This has the effect of reducing the efficiency of the cooler, since this dense layer of oil is not as readily renewed. Even viscous liquids, however, will not maintain the "laminar" character of this described flow if the course of the flow is around sharp corners. Hence the designers of coolers baffle the flow of the oil, to cause it to travel a zigzag course, and at each abrupt change in the direction of the flow of the oil a certain amount of disturbance is caused in the laminar flow of the liquid, which facilitates the exchange of heat.

The question of heat transfer is important. Mineral oils do not readily transmit heat, and, according to A. G. Christie, Assoc. Prof. of M. E. at Johns Hopkins University, "It has been found that the heat transfer is about 15 to 20 B. T. U. per square foot per degree difference in temperature per hour. This is low when compared with a heat transfer of from 350–400 B. T. U. per square foot per hour per degree difference in temperature, which Mr. Christie states is usual in a steam condenser."

The Schutte & Koerting Company, who are manufacturers of oil coolers, make the following recommendations:

"It is better to use a large quantity of oil, circulating at a low temperature drop (without going below a certain minimum), than a small amount of oil circulating at a large temperature drop. It is better not to pass the oil through bearings at too low a temperature, since cold oil is not as capable of absorbing and carrying away heat as is oil at a higher temperature. Fast circulation is a factor in the efficiency of a forced-feed lubricating system, as the warm oil from the bearings should be removed quickly, in order not to obstruct the incoming cooled oil from the cooler."

An important point in the construction of an oil cooler is the arrangement of the packing, since the responsibility of preventing any of the cooling water from mixing with the oil rests upon it.

OIL COOLERS WITH NATURAL CIRCULATION.—Mr. M. Boella, of the Italian Corps of Naval Architects, in an article in *Rivista Marittima,* makes the following statement as deduced from the results of numerous tests he has conducted on oil coolers: "The efficiency of heat transmission in coolers having natural circulation depends upon the regularity with which the oil descends in the horizontal strata, this being greater the slower the flow of the oil. But, on the other hand, the trans-

mission of heat between two fluids through an intervening wall is generally more active, the greater the viscosity of the fluid in contact with the wall. These two conditions are contradictory, and the effect is to limit the efficiency of the heat transmission."

The coefficient of heat transmission for an oil cooler is the number of B. T. U. per square foot, per degree Fahr. difference in the temperature obtained.

OIL COOLERS WITH FORCED CIRCULATION.—It has been found more efficient for the oil to be passed inside rather than outside of the tubes of a cooler having the tube construction. From a theoretical standpoint, a cooler with small tubes and high velocities with the oil passing through the tubes is more effective, but requires the pump used in the circulating system to work against a higher pressure. With rotary pumps, generally found in the unit system, such as a turbine unit, there is a greater slip in the pump with hot oil.

With a forced-circulation cooler, the position of the apparatus and the direction of oil flow are of no importance. The tendency to form a dense stratum of oil over the cooling surfaces is present in the forced-feed type, as in the natural-circulation type. This is largely overcome in the forced type, by high speeds of flow and baffled paths, which tend to break up the inert oil film.

DATA ON OIL COOLERS.—The U. S. Naval Experiment Station found, that the transmission coefficient of surface per degree of temperature difference, varied from 39 to 125. Mr. Boella, of the Italian Corps of Naval Architects, showed that the transmission coefficients ranged from 33 to 180.

Authorities recommend that the same coefficient of heat transmission for figuring cooling surface should not be used for oil coolers as for condensers and feed water heater practice.

USES OF OIL COOLERS.—Oil coolers are widely used for the cooling of oil used in the following-named apparatus:

(*a*) Oil from steel quenching tanks.

(*b*) Electric transformer oils.

(*c*) Oil used for cooling the pistons of internal-combustion engines.

(*d*) Oils used in forced-feed circulating systems, particularly in connection with steam turbine bearing lubrication.

TYPES OF COOLERS

MULTIWHIRL OIL COOLERS.—Fig. 1, Sec. 8a, shows a sectional view of the Multiwhirl Oil Cooler, and Fig. 2, Sec. 8a, shows the cooler with an end removed and the tubes drawn out.

This cooler seems to present the latest improved design. There is a low pressure drop when it is used, and the whirling action given the oil, by means of the helical baffles, brings the oil particles to the cooling surface with an unusually low-pressure drop.

There are a number of small tubes arranged in two pass. At one end they are rolled into a fixed tube plate and at the other end in a floating head, which allows free expansion on change in temperature and eliminates expansion strains. The cooling water is passed through the tubes and the oil through the shell.

The cooler is made in sizes from 5 square feet of transfer surface to 450 square feet. This cooler may be installed in any position.

SCHUTTE & KOERTING COOLERS.—Fig. 3, Sec. 8a, shows a sectional view of the S. & K. Oil Cooler made by the Schutte & Koerting Company, of Philadelphia. The tubes are held together in the form of a bundle. The water passages can be cleaned by simply removing the cover, without disconnecting any of the pipes, and the entire bundle can be removed. It is recommended that these coolers be erected in a vertical position, in order that the flow of the liquids will be more uniform, and the sediment in the oil will settle to the bottom of the cooler, whence it can be easily removed.

COUNTER-CURRENT OIL COOLERS.—Fig. 4, Sec. 8a, shows a Sims Counter-current Oil Cooler. The hot oil from the bearings passes through the inner coil and the cooling water through the outer coil.

COOLING OF QUENCHING TANK OIL.—Fig. 5, Sec. 8a, shows the method of connecting the S. & K. Cooler in a circulating system for the purpose of cooling oil used in quenching tanks which are used for the heat treating of steel. This method will produce better results than can be obtained by the old method of cooling the oil by water ducts or coils, as is commonly done, as the circulation of the oil with the old method is very poor, particularly after the metal has been put in or removed from the tank.

COOLING OF TRANSFORMER OILS.—When cooling the oil used in a transformer installation, it is preferable to use air as a cooling medium rather than water, as the possibility of the water getting into the oil and reducing its dielectric properties is very likely. Sometimes the cooling is effected by erecting a stack and drawing air through the cooler by natural draft, or the air may be forced through the cooler by means of a fan.

CLEANING OIL COOLERS.—When the cooling water is run through return bends, spiral tubes and other crooked passages, it is very difficult to run a scraper through the cooler for cleaning purposes. The water may contain sediment, which will reduce the efficiency of the cooler, both by depositing a coating of silt on the outside of the cooling surface and by retarding the water flow. Coolers having water tubes that are straight are at a big advantage in this respect.

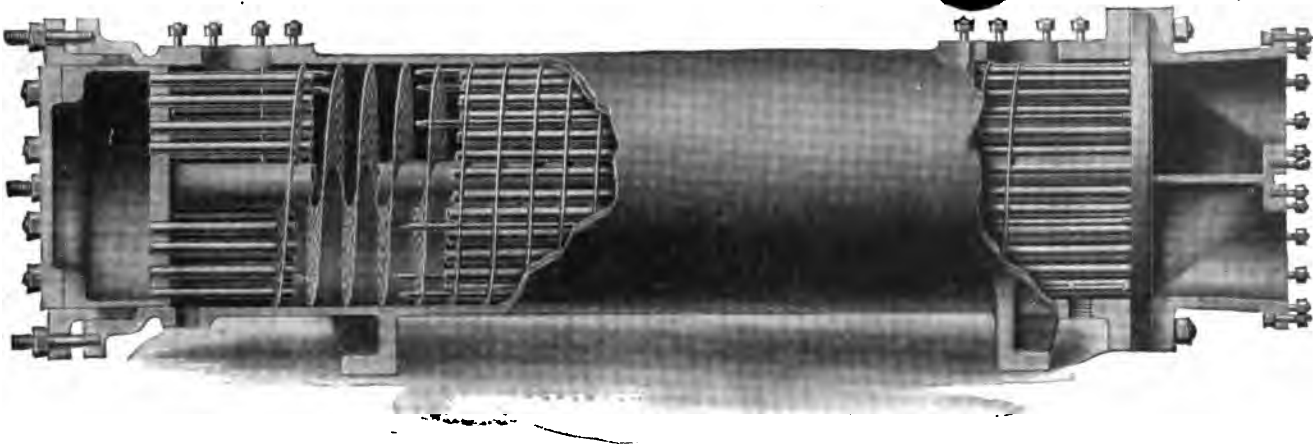


FIG. 1. SEC. 8a.—Multiwhirl oil cooler.

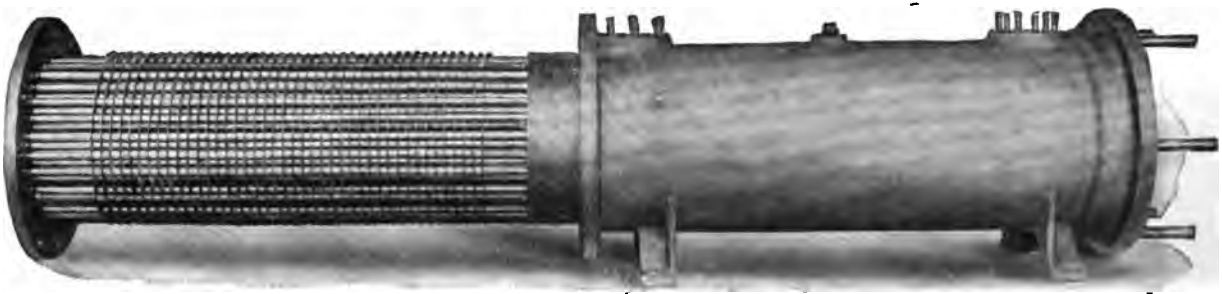


FIG. 2. SEC. 8a.—Multiwhirl oil cooler.

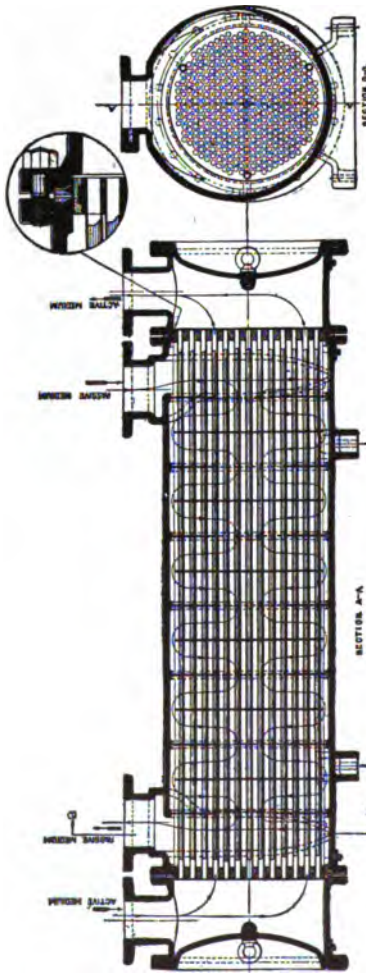


FIG. 3. SEC. 8a.—Sectional view of an oil cooler, manufactured by the Schutte & Koerting Company.

FIG. 4. SEC. 8a.—Counter current oil cooler.

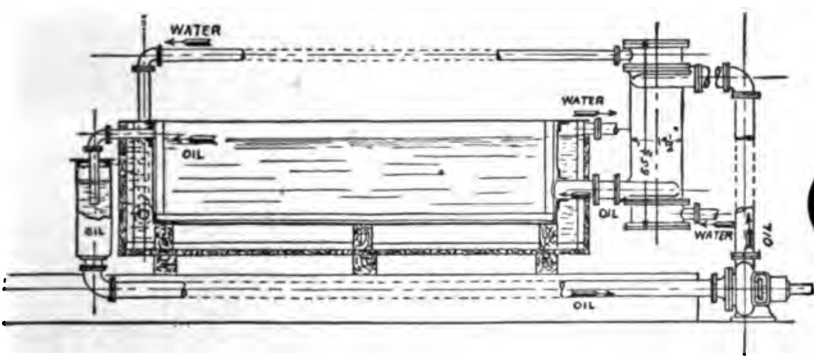


FIG. 5. SEC. 8a.—Method of cooling quenching tank oil with oil cooler.

SECTION 9

OIL STORAGE AND HANDLING

TANKS

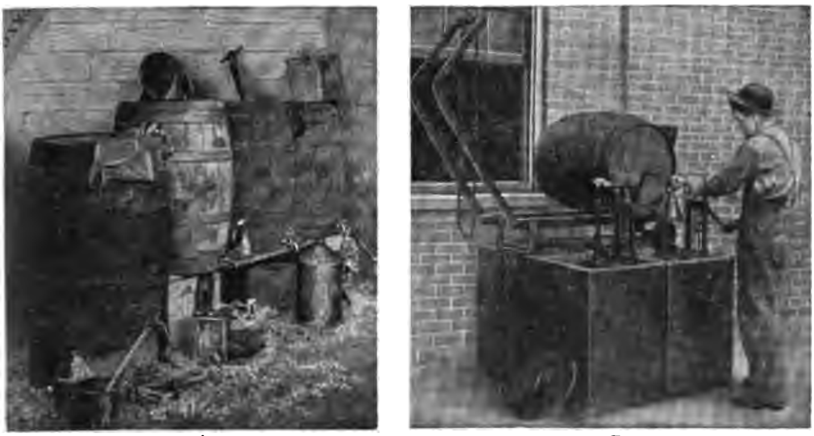
DIMENSIONS AND SPECIFICATIONS OF HEAVY METAL, CYLINDRICAL STORAGE TANKS*

Approx. cap. gallons	Approx. inside dimensions in inches		3-16 Shell		1/4 Shell		5-16 Shell	
	Diameter	Length	Heads	Approx. weight	Heads	Approx. weight	Heads	Approx. weight
65	24"	34"	3/16"	230	1/4"	310		
117	24"	60"	3/16"	360	1/4"	490		
165	30"	54"	3/16"	420	1/4"	560		
215	30"	70"	3/16"	525	1/4"	670		
250	36"	57"	3/16"	625	1/4"	750		
345	42"	58"	3/16"	700	1/4"	850		
420	42"	70"	3/16"	800	1/4"	950		
500	42"	84"	3/16"	900	1/4"	1080		
550	42"	92"	3/16"	1020	1/4"	1250		
645	42"	108"	3/16"	1000	1/4"	1360		
750	48"	96"	3/16"	1225	1/4"	1600		
940	48"	120"	3/16"	1475	1/4"	1875		
1000	54"	101"	3/16"	1490	1/4"	1900		
1100	54"	111"	3/16"	1575	1/4"	2000		
1200	54"	122"	3/16"	1680	1/4"	2150		
1500	60"	123"	3/16"	1900	1/4"	2550		
1810	60"	148"	3/16"	2180	1/4"	2925		
2010	66"	136"	3/16"	2300	1/4"	3100		
2500	66"	169"	3/16"	2700	1/4"	3640		
3020	66"	204"	3/16"	3300	1/4"	4270		
3525	72"	200"	3/16"	3600	1/4"	4640		
4000	72"	227"	3/16"	3950	1/4"	5200		
5000	78"	242"	...	....	1/4"	5925		
6000	78"	290"	...	....	1/4"	6910		
7000	84"	292"	...	....	1/4"	7305		
8010	84"	334"	...	....	1/4"	8240		
9000	90"	327"	...	....	1/4"	8580		
10080	96"	322"	...	....	1/4"	9230		
10525	96"	336"	...	....	1/4"	9580		
11025	96"	352"	...	....	...	....	5/16"	12470
12000	108"	303"	...	....	...	....	5/16"	13270

This table covers standard dimension tank. Figured from standard mill sheets and standard flanged heads. They are properly proportioned to give the greatest degree of satisfactory service.

* Courtesy Wayne Oil Tank and Pump Co., Fort Wayne, Ind.

SPECIFICATIONS OF CYLINDRICAL TANKS.—The following specifications are those of a prominent tank manufacturer of riveted, heavy metal storage tanks. "All steel plate used conforms to the specifications adopted by the American Association of Steel Manufacturers for special open-hearth soft steel, having an ultimate strength of from 45,000 to 55,000 pounds per square inch, an elastic limit of not less than one-half of its ultimate strength, and with an elongation capable of bending flat on itself without fracture outside of bent portion. All plates to be full thickness over their entire surface. * * * All courses of steel to be full lapped and riveted metal to metal. No felt, paper, filler of any kind or rusting compound used. All seams to be beveled and carefully caulked by air hammer under pressure. All rivet holes to be machine punched and spaced to insure accurate fit of rivets. * * * To be tested by air pressure equal to 25 per cent. more than the pressure exerted on the tank when entirely full of liquid. * * * Equipment to include fill



A *B*

FIG. 1. SEC. 9.—*A*, Wasteful, inefficient method of handling oil. *B*, Scientific, efficient method. (Courtesy S. F. Bowser & Co.)

pipe, 2-inch, with vented fill cap and two keys; standard fill pipe; air-vent protector; three long boss malleable flanges, for vent, fill and suction. Minimum gauge of material:

1 to 4,000	gallons,	3/16" shell,	3/16"	heads.
4,001 to 10,500	gallons,	1/4" shell,	1/4"	heads.
10,501 to 20,000	gallons,	5/16" shell,	5/16"	heads.
20,001 to 30,000	gallons,	3/8" shell,	3/8"	heads.

"Every part of tank to be free from flaws, twists or other defects, and approved by fire underwriters. Each tank to be thoroughly cleaned of any dirt or scale and given two coats of heavy rust-resisting paint brushed on."

CYLINDRICAL TANKS
DIMENSIONS, CAPACITIES AND SHIPPING WEIGHTS

The following table gives the standard dimensions and approximate shipping weights of large cylindrical tanks:

	Black Steel								Galv. or Black Steel			
Approx. capacity gallons*	Outside dimensions		1/4" Shell		5/16" Shell		3/8" Shell		Outside dimensions		3/16" Shell	
	Approx. diameter	Length	Heads	Approx. shipping weight	Heads	Approx. shipping weight	Heads	Approx. shipping weight	Approx. diameter	Length	Heads	Approx. shipping weight
800	56"	85 1/2"	1/4"	1595	5-16"	2040	3/8"	2215	55 1/2"	85 1/2"	3-16"	1175
1000	62"	85 1/2"	1/4"	1935	5-16"	2185	3/8"	2480	61 1/2"	85 1/2"	3-16"	1500
1200	62"	98 3/4"	1/4"	2185	5-16"	2570	3/8"	2930	61 1/2"	98 3/4"	3-16"	1715
1500	62"	122 3/4"	1/4	2585	5-16"	3085	3/8"	3515	61 1/2"	122 3/4"	3-16"	1975
1800	74"	102 3/4"	5-16"	2885	5-16"	3395	3/8"	3870	73 1/2"	102 3/4"	3-16"	2450
2000	74"	114 3/4"	5-16"	3075	5-16"	3535	3/8"	4150	73 1/2"	114 3/4"	3-16"	2555
2500	74"	142 3/4"	5-16"	3580	5-16"	4275	3/8"	4880	73 1/2"	142 3/4"	3-16"	2945
3000	74"	170 3/4"	5-16"	4050	5-16"	4870	3/8"	5565	73 1/2"	170 3/4"	3-16"	3315
3500	86"	148 3/4"	5-16"	4420	5-16"	5265	3/8"	6020	73 1/2"	198 3/4"	3-16"	3700
4000	86"	168 3/4"	5-16"	4805	5-16"	5755	3/8"	6580	73 1/2"	226 3/4"	3-16"	4085
5000	98"	160 3/4"	3/8"	5725	3/8"	6760	3/8"	7455	85 1/2"	210 3/4"	5-16"	4595
6000	98"	192 3/4"	3/8"	6470	3/8"	7700	3/8"	8535	85 1/2"	252 3/4"	5-16"	5170
7000	98"	244 3/4"	3/8"	7320	3/8"	8790	3/8"	9780	91 1/2"	254 3/4"	5-16"	5770
8000	104"	226 3/4"	3/8"	7960	3/8"	9545	3/8"	10615	91 1/2"	290 3/4"	5-16"	6345
9000	104"	254 3/4"	3/8"	8630	3/8"	10395	3/8"	11585	97 1/2"	290 3/4"	3/8"	7065
10500	110"	265 3/4"	3/8"	9215	3/8"	11075	3/8"	12330	97 1/2"	322 3/4"	3/8"	7605
12000	116"	272 3/4"	3/8"	10345	3/8"	12445	3/8"	13865				
13000	116"	294 3/4"	3/8"	11025	3/8"	13320	3/8"	14865				
14000	116"	316 3/4"	3/8"	11690	3/8"	14155	3/8"	15825				
15000	122"	308 3/4"	3/8"	12095	3/8"	14610	3/8"	16305				
16000	122"	328 3/4"	3/8"	12735	3/8"	15415	3/8"	17230				
18000	122"	368 3/4"	3/8"	13890	3/8"	16880	3/8"	18915				
20000	128"	372 3/4"	3/8"	14670	3/8"	17805	3/8"	19915				
25000	128"	466 3/4"	3/8"	17690	3/8"	21600	3/8"	24280				

NOTE—If approximate inside dimensions are wanted, the following instructions will apply: On 3/16", 1/4", 5/16" and 3/8" tanks deduct 2 1/2" from the outside diameter; on 3/16", 1/4", 5/16" and 3/8" tanks up to 1100 gallons inclusive, deduct 3 1/2" from outside length; on tanks larger than 1100 gallons deduct 3/4" from outside length; 3/16" tanks are made either of galvanized or black steel; 1/4", 5/16" and 3/8" tanks are made of black steel only.

* See index for tank capacities. (P. S. Bowser & Co., Inc.)

DATA ON RECTANGULAR TANKS.—Rectangular tanks should be set perfectly level on concrete, brick, stone or wood foundations. There should be at least 16 inches working or head room to properly admit pipe work. Rectangular tanks should be at least 16 inches apart, to provide room for inspection and caulking.

Cylindrical tanks instead of rectangular tanks should be used if they are to be buried under ground.

Rectangular tanks should be used in preference to cylindrical tanks for location in a basement, vault, oil house, etc., as they require less room and can be much more easily arranged, except for large storage. Do not use them in connection with air or hydraulic-pressure systems.

CAPACITIES AND DIMENSIONS, RECTANGULAR TANKS

Rated	Inside dimensions in inches				Approximate weight	Rated	Length	Inside dimensions in inches			Approximate weight
Capacity gallons	Length	Height	Width	Gauge		Capacity gallons		Height	Width	Gauge	
500	66″	48″	37″	3/16″ & ¼″	1150	5000	134″	90″	96″	¼″	6100
500	66″	54″	33″	3/16″ & ¼″	1180	5000	106″	114″	96″	¼″	6110
500	60″	60″	33″	3/16″ & ¼″	1200	6000	214″	90″	72″	¼″	7270
800	66″	60″	48″	3/16″ & ¼″	1856	6000	170″	114″	72″	¼″	7034
800	64″	54″	54″	3/16″ & ¼″	1824	6000	184″	90″	84″	¼″	7880
800	58″	54″	60″	3/16″ & ¼″	1792	6000	146″	114″	84″	¼″	7140
1000	74″	66″	48″	3/16″ & ¼″	2124	6000	162″	90″	96″	¼″	7060
1000	66″	66″	54″	3/16″ & ¼″	2097	6000	128″	114″	96″	¼″	8891
1000	66″	60″	60″	3/16″ & ¼″	2099	7000	250″	90″	72″	¼″	8260
1100	82″	66″	48″	3/16″ & ¼″	2278	7000	198″	114″	72″	¼″	7975
1100	72″	66″	54″	3/16″ & ¼″	2214	7000	214″	90″	84″	¼″	8230
1100	66″	66″	60″	3/16″ & ¼″	2361	7000	170″	114″	84″	¼″	7940
1200	78″	66″	54″	3/16″ & ¼″	2336	7000	188″	90″	96″	¼″	7920
1200	70″	66″	60″	3/16″ & ¼″	2304	7000	148″	114″	96″	¼″	7690
1200	64″	60″	72″	3/16″ & ¼″	2312	8000	288″	90″	72″	¼″	9900
1500	98″	66″	54″	3/16″ & ¼″	2753	8000	226″	114″	72″	¼″	9450
1500	88″	66″	60″	3/16″ & ¼″	2718	8000	246″	90″	84″	¼″	9300
1500	74″	66″	72″	3/16″ & ¼″	2647	8000	194″	114″	84″	¼″	8920
1800	90″	78″	60″	¼″	3044	8000	214″	90″	96″	¼″	8790
1800	74″	78″	72″	¼″	3086	8000	170″	114″	96″	¼″	8450
1800	64″	78″	84″	¼″	3065	9000	254″	114″	72″	¼″	10473
2000	100″	78″	60″	¼″	3296	9000	276″	90″	84″	¼″	10334
2000	84″	78″	72″	¼″	3241	9000	218″	114″	84″	¼″	9860
2000	72″	78″	84″	¼″	3265	9000	242″	90″	96″	¼″	9865
2500	108″	90″	60″	¼″	3781	9000	190″	114″	96″	¼″	9500
2500	104″	78″	72″	¼″	3690	10000	282″	114″	72″	¼″	12300
2500	88″	78″	84″	¼″	3755	10000	242″	114″	84″	¼″	10760
3000	108″	90″	72″	¼″	4563	10000	268″	90″	96″	¼″	10740
3000	92″	90″	84″	¼″	4241	10000	212″	114″	96″	¼″	10390
3000	82″	90″	96″	¼″	4210	11000	310″	114″	72″	¼″	12140
3500	126″	90″	72″	¼″	4816	11000	266″	114″	84″	¼″	11650
3500	109″	90″	84″	¼″	4680	11000	232″	114″	96″	¼″	12200
3500	94″	90″	96″	¼″	4910	12000	338″	114″	72″	¼″	11840
4000	144″	90″	72″	¼″	5230	12000	290″	114″	84″	¼″	12580
4000	114″	114″	72″	¼″	5140	12000	234″	114″	96″	¼″	11850
4000	124″	90″	84″	¼″	5380	13000	314″	114″	84″	¼″	13400
4000	98″	114″	84″	¼″	5391	13000	276″	114″	96″	¼″	12700
4000	86″	114″	96″	¼″	5260	14000	338″	114″	84″	¼″	14260
5000	180″	90″	72″	¼″	6318	14000	296″	114″	96″	¼″	13500
5000	142″	114″	72″	¼″	6200	15000	318″	114″	96″	¼″	14330
5000	154″	90″	84″	¼″	6350	16000	338″	114″	96″	¼″	15100
5000	122″	114″	84″	¼″	6290						

*NOTE—The above table is for type (S) tanks. The sizes in heavy type are standard. All sizes are figured on using stock plates—Each tank fitted with a 10″ x 16″ bolted machine-faced manhole with airtight gasket 1–2″ flange for fill, 1–3″ flange for suction, 1–1″ flange for vent, 1–½″ flange for indicator.

Dimensions given are inside. Add 3″ to length and 4″ to height for over-all dimensions. (Courtesy Wayne Oil Tank and Pump Co., Fort Wayne, Ind.)

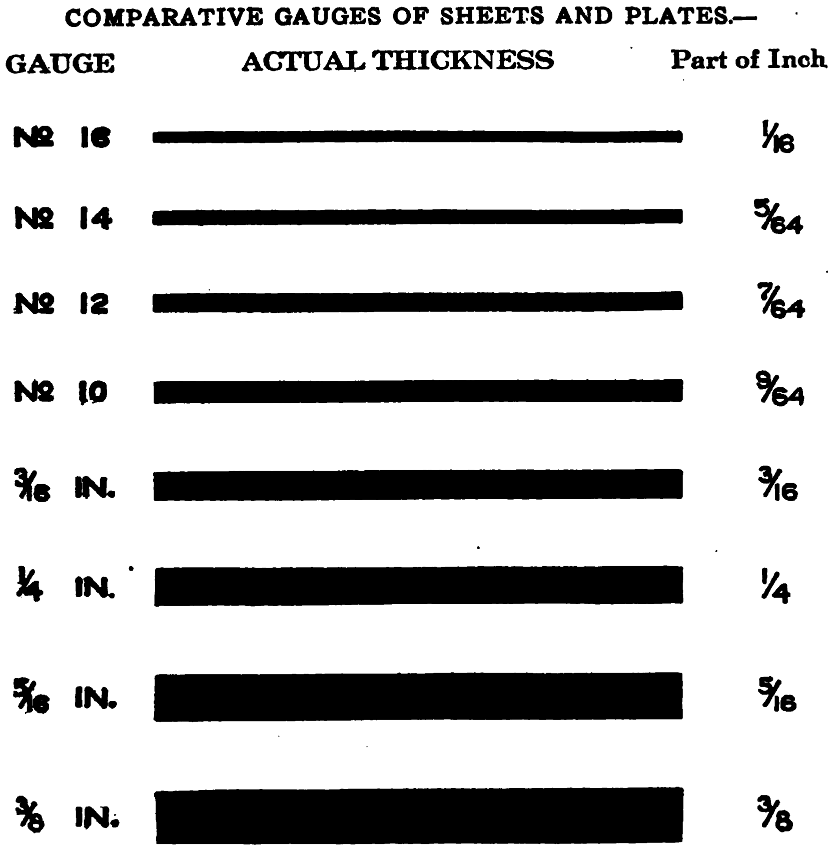


Fig. 2. Sec. 9.—Comparative gauges of sheets and plates for tank use. (Courtesy S. F. Bowser & Co.)

EFFECT OF TANK COLOR.—(Bulletin 155, Petroleum Tech. 41, Department of Interior, U. S. Bureau of Mines, by C. P. Bowie, 1918, p. 58). Mr. Bowie in connection with his discussion on "Oil Storage" says: "It is reported that tests have demonstrated that evaporation from tanks painted white averages about 1 to 1 1/4 per cent. less than from tanks painted red, and about 2 1/2 per cent. less than from tanks painted black. These figures have not been verified, but tests made by the Institute of Industrial Research (H. A. Gardner on "The Heat-Reflecting Properties of Colors Applied to Oil and Gas Storage Tanks," Circular 44, Paint Manufacturing Association of U. S.; Educational Bureau, Sci. Sec., January, 1917, p. 1) show that dark-colored paints absorb heat to a considerable degree, and paints presenting a highly glossy surface are less absorptive of thermal rays than those presenting a matte surface."

Mr. Bowie gives the results of some experiments, wherein small tanks containing benzine were painted in various colors (gloss finish) and then subjected to the rays of a powerful arc light for 15 minutes. At the end of that period the rise in temperature of the benzine was found to be as follows for various colors:

RISE IN TEMPERATURE OF BENZINE STORED IN TANKS OF VARIOUS COLORS*

	Rise in temp.° Fahr.
Tin plate (tank plated with tin)	19.8
Aluminum paint	20.5
White paint	22.5
Light cream paint	23.0
Light pink paint	23.7
Light blue paint	24.3
Light gray paint	26.3
Light green paint	26.6
Red iron oxide paint	29.7
Dark Prussian blue paint	36.7
Dark chrome green paint	39.9
Black paint	54.0

Mr. Bowie states that, as shown, tin plating and aluminum paints gave the best results. However, neither of these finishes is practical for outside work, as iron coated with tin corrodes rapidly, and aluminum paint soon loses its gloss and becomes flaky. As is shown, the rise in temperature of the benzine in the tank painted black was 140 per cent. higher than that in the tank painted white.

CORROSIVE ACTION OF PETROLEUM AND FATTY OILS ON CONCRETE.—Cement and concrete are resistant to the action of tars and mineral oil. Concrete reservoirs for mineral oils have been found satisfactory. Fatty oils, on the other hand, have a decomposing action upon cement and concrete. (Tonindustrie-Ztg., 1912, No. 100.)

* Table from "Oil Storage and Reservoirs," by C. P. Bowie, U. S. Bureau of Mines.

PNEUMERCATOR

This instrument is used for measuring the contents of tanks, reservoirs, standpipes, etc. Some of the advantages claimed for the pneumercator are: The registering portion of the instrument can be located at any distance above or below the tank. The accuracy of the instrument is not changed by temperature changes. It works equally well on tanks

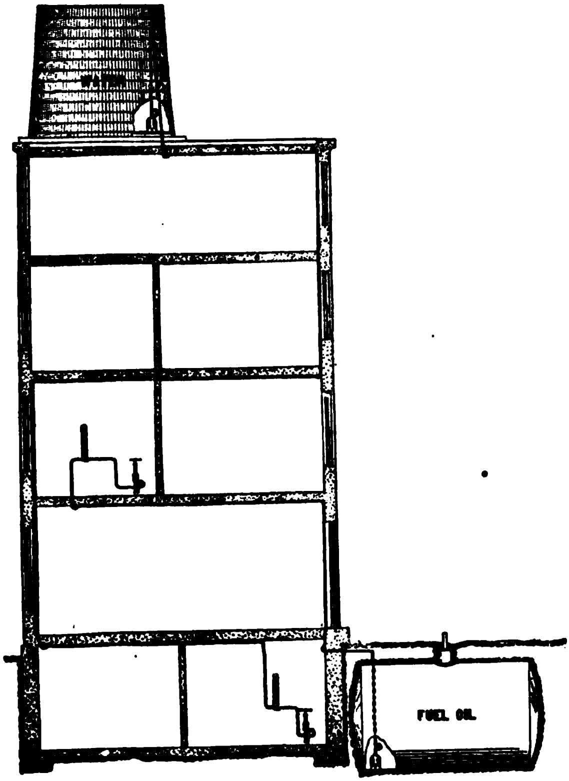


FIG. 3. SEC. 9.—Pneumercator installation.

open to the atmosphere, under vacuum or under varying pressure. If the contents of the tanks freeze, the pneumercator will indicate it.

Essentially the pneumercator consists of a balance chamber; a mercury or other gauge, which is calibrated in feet and inches and the corresponding weight or volume; a pump or other means of furnishing compressed air; a control valve or valves connected to the gauge and also connected through small piping to the balance chamber and the air pump.

The balance chamber is located at a predetermined point below the surface of the liquid to be measured and with direct opening to the

liquid. The liquid tries to enter the balance chamber and by its own weight compresses the air in that chamber and in the connecting pipe line to the mercury gauge, which is the registering part of the instru-

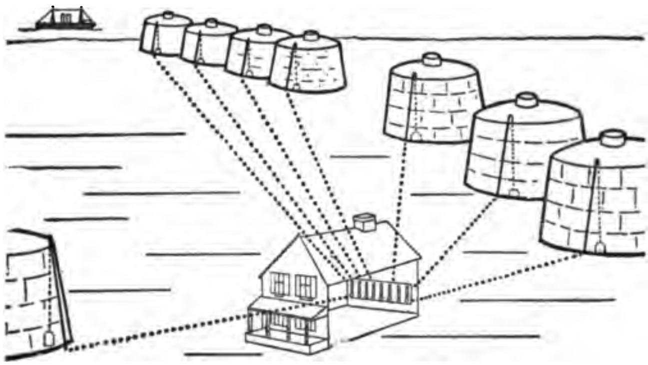


FIG. 4. SEC. 9.—Pneumercator connected to battery of tanks.

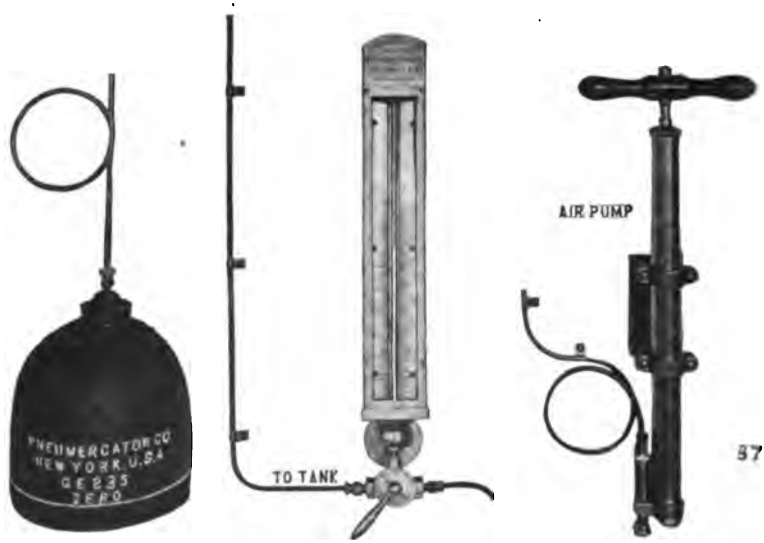


FIG. 5. SEC. 9.—Pneumercator equipment.

ment, thus causing the mercury to rise or fall in direct ratio to the pressure exerted.

Fig. 3, Sec. 9, shows a typical installation of the pneumercator. One instrument is connected to a 12-foot water tank on the roof and the other instrument is connected to a 10-foot tank under ground, for fuel

oil. This illustrates its use for either open tanks or tanks under pressure or vacuum.

Annunciators, electrically operated, can be attached to any model to indicate a predetermined maximum, minimum, mean or other levels.

Fig. 4, Sec. 9, shows how a battery of tanks may be fitted with the pneumercator and the instruments made to register at a central station.

Fig. 5, Sec. 9, shows the pneumercator equipment.

Another model of Pneumercator Tank Gauge which has recently been developed is adjustable to variations in specific gravity or Baumé, and when set at the indicated specific gravity of the liquid in the tank reads directly into feet, inches and quarter inches, and if desired, the corresponding gallons of the liquid in the tank. Conversely, if the depth is known, the instrument adjusted until the feet and inch scale reads to this depth, the average specific gravity or Baumé of the tank contents can be read directly on the scale of the instrument.

All models of Pneumercator Tank Gauges can be applied equally well to tanks afloat or on shore with the exception of the specific gravity gauge, which is for shore purposes only.

The instrument is in use on many types of oil-burning vessels of the United States Navy and vessels of the U. S. Emergency Fleet Corporation.

The instruments for shore use are largely used in connection with any liquid or semi-liquid, fluid enough to seek its own level.

Their main advantage is that they provide a perpetual inventory of the contents of the tank, when the tank is filled or emptied.

The indicating portion of the instrument can be located at a distance, either above or below the tank, and contains within itself a means of checking and proving the accuracy of the reading.

EXTINGUISHING FIRES

EXTINGUISHING FIRES CAUSED BY BURNING LIQUIDS.—(Technical Paper 127, "Petroleum Technology," U. S. Bureau of Mines, by Geo. A. Burrell. "There are two principal methods of extinguishing burning liquids, as follows:

"1. To form a blanket of gas or solid material over the burning liquid and cut off the air (oxygen) supply.

"2. To dilute the burning liquid with a non-inflammable extinguishing agent that will mix with it.

"Water may be used for extinguishing burning liquids such as denatured alcohol, wood alcohol, acetone, etc., that are miscible with it. If such a liquid as gasoline, which is not miscible with water, catches fire, the application of water produces little or no effect except to spread the burning liquid, and thus scatter the fire over a larger area. However, the addition of a large quantity of water to a small quantity of burning oil, by its cooling effect, may aid in extinguishing the fire. * * * Of materials used to form a blanket of gas or solid liquid over the burning fluid, thus cutting off the oxygen supply, several are in common use. They include sawdust, sand, carbon tetrachloride, and the so-called foam or frothy mixtures.

"The efficiency of sawdust is due to its floating for a time on the liquid and excluding the oxygen of the air. Sawdust itself is not easily ignitable, and when it does ignite burns without a flame. The character of the sawdust or its moisture content is of little or no importance. It may be easily handled for extinguishing small fires when just started by means of long-handled wooden shovels. * * * Carbon tetrachloride, the basis of various chemical fire extinguishers, if thrown on a fire forms a heavy, non-inflammable vapor over the liquid, and mixes readily with oils, waxes, japan, etc. The vapor is about five times as heavy as air. * * * When thrown on a fire it produces black smoke. * * * The efficacy of carbon tetrachloride depends largely upon the skill of the user. If the liquid in a tank is on fire, the height of the liquid is important. When the liquid is low, the sides of the tank form a wall which retains the vapor, but when the tank is nearly full of a highly volatile liquid, like gasoline, only the most skilled operator can extinguish the fire.

"Installations embracing the use of foam or frothy-liquid mixtures to extinguish fires in large oil storage tanks * * * cause two liquids to mix in a tank, whereupon foam is produced. In one installation, water, bicarbonate of soda and soap bark are used in one tank and acid in another. A fusible link, which will melt at 212° Fahr., releases a hammer, which breaks a glass tank holding the acid. The released acid is led through perforated pipes into the solution, producing a violent ebullition of foam, which finds its way into the tank of burning oil."

PROTECTION OF TANKS.—Usually tanks containing crude oils such as Pennsylvania (light crudes), Ohio, Mid-Continent, Kentucky, Oklahoma, Corning and Mexican, are fitted so that steam can be used to fill the part of the tank over the oil. This steam is usually run into the tanks on the approach of a storm. Generally tanks containing reduced crudes or straight Texas crude do not require the steam as a protection. On the approach of a storm, steam is not generally used for tanks con-

taining 150 and 120 test distillates, nor for tanks containing other distillates, unless the temperature is above 90° F. Steam is used, however, in tanks containing unsteamed distillates (steam-still stock) and sour distillates. It is not usual to turn in steam for tanks containing naphthas, refined oils, gas oils, fuel oils, etc. In case of a fire, the full head of steam is turned into the tank and a water spray on the tank is used. The same treatment is carried out with the tanks surrounding the burning tanks. The above is typical refinery practice.

FOAM SYSTEMS AND MIXTURES.—The chemicals used for producing the foam may be any two compounds that on coming into contact with each other form an abundance of foam. They must not deposit any large amount of sediment after having been in solution for some time. Usually the chemical constituents are so proportioned that when the two are combined in equal parts a maximum amount of foam is produced. Mr. C. P. Bowie, in Bureau of Mines Bulletin, " Extinguishing and Preventing Oil and Gas Fires," states: In the installation at Coalinga the following formula was used:

Solution A.

	Parts by weight.
Water	100
Aluminum sulphate (crystal)	10
Sulphuric acid, 66° B.	1/2

Solution B.

Water	100
Ground glue	1 1/4
Glucose	1/2
Sodium bicarbonate	7 1/2
Arsenious oxide	1/52

The installation was designed to protect four 55,000-barrel oil tanks, each 114 feet 6 inches in diameter; one 37,000-barrel tank, 95 feet 6 inches in diameter; one 30,000-barrel tank, 85 feet in diameter, and two fuel-oil tanks, each about 8 feet in diameter. On the estimate of 6 gallons of foam for 1 gallon of solution, to produce over the surface of all the various tanks a blanket of foam 5 inches thick in 5 minutes, required for delivery of each solution at the following rates:

55,000-barrel tank	550 gallons per minute.
37,000-barrel tank	368 gallons per minute.
30,000-barrel tank	308 gallons per minute.
Fuel tanks, about	6 gallons per minute.

On this basis, Mr. Bowie states that 6200 gallons of each solution would be required to cover all the tanks once with 5 inches of foam. In order to provide an ample supply of solution and to allow a reasonable factor of safety, it was determined to use solution tanks 15 feet in diameter by 11 feet 9 inches in height, each having a capacity of 15,700 gallons.

Mr. Bowie states that other formulas used for foam solutions are as follows:

FORMULA No. 1.

Solution A.

Water	100	parts by weight.
Aluminum sulphate (crystal)	14	parts by weight.
Extract of licorice (powdered)	3	parts by weight.

Solution B.

Water	100	parts by weight.
Sodium bicarbonate	9 1/4	parts by weight.

FORMULA No. 2.

Solution A.

Water	100	parts by weight.
Aluminum sulphate (crystal)	12	parts by weight.
Acetic acid	1/2	part by weight.
Ground glue	1	part by weight.
Glucose	1/4	part by weight.

Solution B.

Water	100	parts by weight.
Sodium bicarbonate	10	parts by weight.
Ground glue	1	part by weight.
Glucose	1/4	part by weight.

PUMPS

DOUBLE-ENDED PUMP.—Fig. 6, Sec. 9, shows a double-ended pump; Fig. 7, Sec. 9, shows a cross-sectional view. This type of pump is intended for use on individual and small central machine and engine oiling systems. The two ends of the pump operate separately of each other. Usually one end pumps dirty oil and the other end pumps clean oil. The pump is usually driven from the valve gear of the engine. The

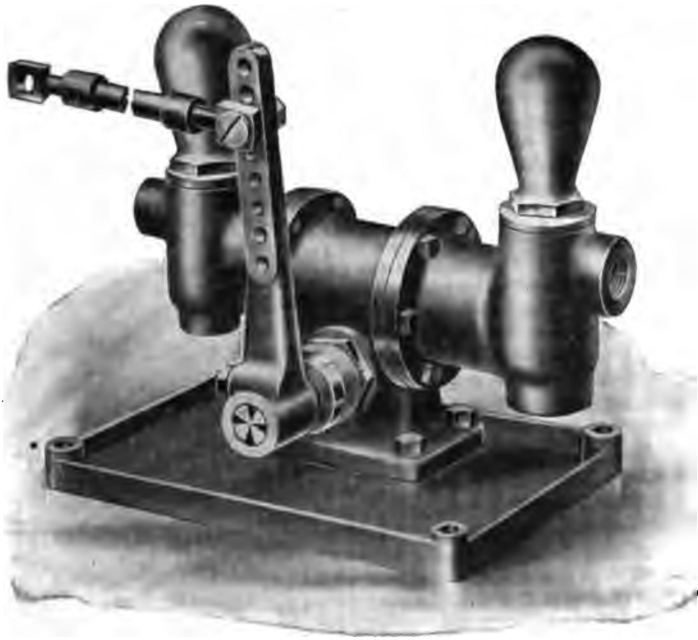


Fig. 6. Sec. 9.—Double-ended oil pump.

quantity of oil pumped depends upon the speed and the stroke of the pump. The following table shows the quantity of oil delivered by the pumps manufactured by the Richardson-Phenix Company, with different degrees of throw for the driving lever. For instance, with a filter rated at 18 to 35 gallons per hour, the lever should have a throw of about 20° if the engine operates at 100 R. P. M., or 40° if the engine operates at 50 R. P. M.

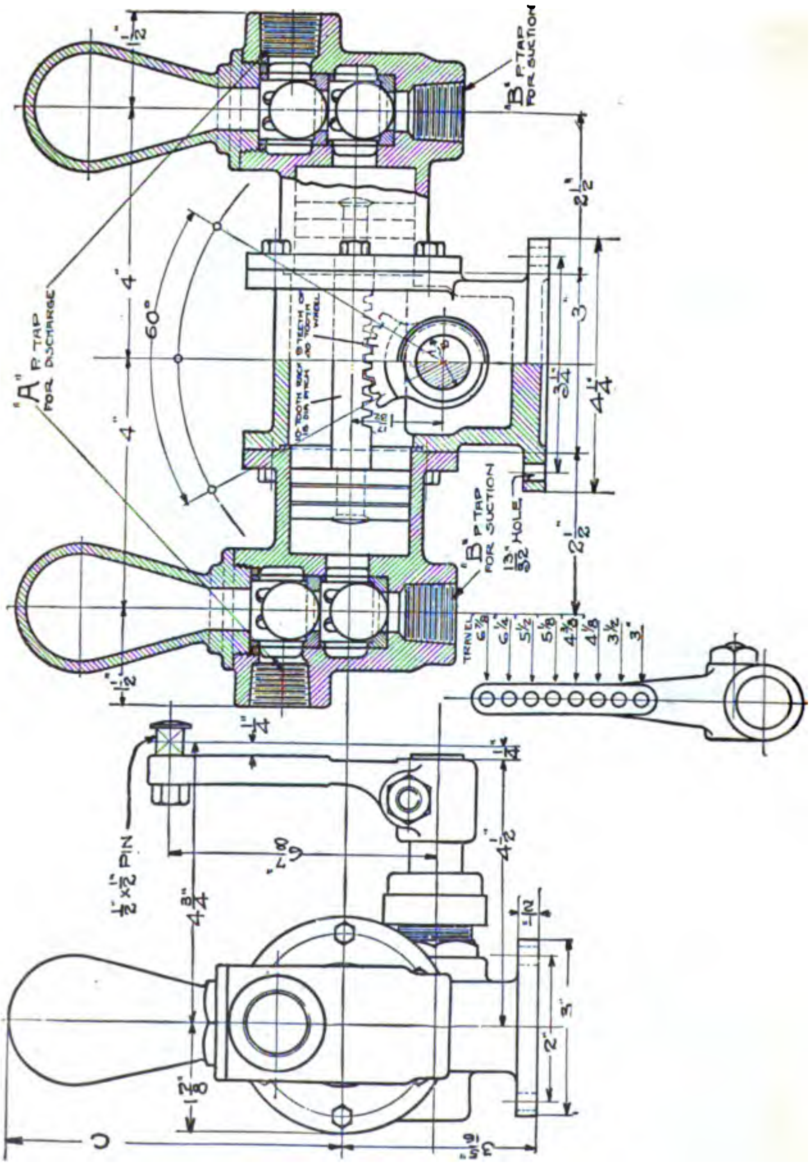


FIG. 7. SEC. 9.—Cross-section view double ended oil pump.

CAPACITY OF ONE END OF PUMP AT VARYING LENGTHS OF STROKE AT 100 R. P. M. (Richardson-Phenix Pumps)

Degrees travel	Straight across travel of centre of driving hole in the outer end of the lever	Gallons pumped per hour
10	$1\frac{3}{16}''$	15.0
20	$2\frac{3}{8}''$	30.0
30	$3\frac{17}{32}''$	45.0
40	$4\frac{11}{16}''$	60.0
50	$5\frac{13}{16}''$	75.0
60	$6\frac{7}{8}''$	90.0

INCLINABLE PUMP PLUNGER.—Fig. 8, Sec. 9, shows an exterior view and an outline drawing of an inclinable plunger pump for individual oiling system. It is bolted to a horizontal or a vertical part of the engine or to the floor, and is driven by some reciprocating part of

FIG. 8. SEC. 9.—Inclinable plunger oil pump.

the engine. This type of pump at full stroke (Richardson-Phenix type) will deliver 40 gallons of oil per hour at 100 strokes per minute against a 10-foot head. The delivery can be regulated by adjusting the driving pin.

REMOTE CONTROL SELF-REGISTERING PIPE-LINE MEASURE.—This apparatus is shown at *A* in Fig. 9, Sec. 9. It is used to

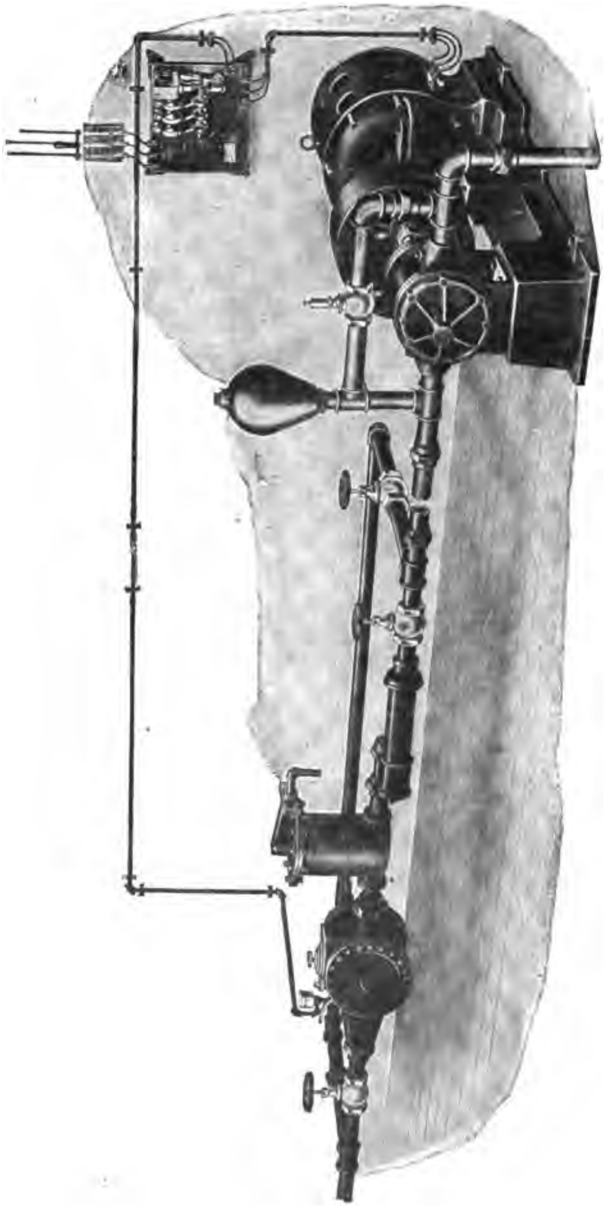


FIG. 9. SEC. 9.—Rotary pump, pipe line steamer, air separator. remote central measure.

accurately deliver predetermined quantities of oils. The point of delivery may be remotely located. It is useful in filling barrels, cans, tank wagons, etc. It can be installed in a central oil house, where lubricants are served out to various people and a record is desired.

PIPE-LINE STRAINER.—This apparatus is inserted in the delivery lines to catch chips, dirt, etc., so that the meter will be protected from damage. The strainer is shown in Fig. 9, Sec. 9. It is useful to install in fill lines, to stop dirt that may be carried into the meter.

AIR RELEASE.—This apparatus is designed to be placed between the registering meter and the source of supply when the oil is supplied under pressure. It is intended to remove any air that may have gotten into the pipe line and which would cause incorrect readings of the meter. It is shown installed in Fig. 9, Sec 9.

REMOTE - CONTROL VALVES.—These valves are designed to be used at the discharge end of a pipe line, for starting and stopping the power pump that is moving the oil. By turning the handle of the valve it is so arranged that the pump is started and stopped. This is accomplished by means of an electric switch on the valve, which is connected with the starting switch of the pump motor.

FIG. 10. SEC. 9.—Belt driven rotary oil pump.

CIRCULATING PUMPS.—Fig. 9, Sec. 9, also shows a rotary pump equipped with an electric motor, by-pass and a pressure valve. This type of pump is useful in circulating oil through continuous oiling systems, cutting-oil reclaiming systems, cooling coils, etc.

The equipment shown in Fig. 9, Sec. 9 is manufactured by S. F. Bowser & Co., Inc.

SPECIFICATIONS, ROTARY PUMP

(For Direct-Connected Motor Only)

(S. F. Bowser & Co. No. 709 Pump)

Size	Floor space	Size suction	Size discharge	Speed R. P. M.	Gals. per minute	Horsepower required
¾"	15" x 28"	1"	¾"	160	7	½ to ¾
1"	16" x 31"	1¼"	1"	160	11	½ to 1
1½"	20" x 34"	2"	1½"	150	28	1 to 1½
2"	21" x 40"	2½"	2"	140	46	1 to 2
2½"	30" x 57"	3"	2½"	85	60	2 to 3
3"	35" x 60"	3½"	3"	85	100	3 to 4

NOTE. The above table is figured on the basis of a ten-foot suction and a working pressure of ten (10) pounds.

Where cylinder oil and other heavy oils are to be handled, they should be kept at a temperature of at least 80° Fahr., and 20 per cent. should be deducted from the above capacities and 20 per cent. added to the horsepower. If the horizontal suction is over 25 feet, the size of the suction should be increased one size of pipe, from 50 to 100 feet increases the size of pipe two sizes. The suction should not go over 100 feet.

Do not use the 3/4-inch and 1-inch pipes for cylinder oil except under very favorable conditions.

OIL PUMPS.—Fig. 10, Sec. 9, shows a rotary pump for use in supplying oil for cutting tools on metal-working machines, such as screw machines, lathes, bolt cutters, etc. To obtain the best results, the pump should be placed as near as possible to the level of the oil in the tank. Driving pulley 3 1/2-inch diameter, 1-inch belt (No. 8 oil pump). The capacities are as in the following table:

Revolutions per minute	Capacity quarts per minute	Height forced	Suction	Discharge	Net weight
100	1	Up to 12 ft.	¼"	¼"	8½ lb.
100	½	Up to 16 ft.	¼"	¼"	8½ lb.
300	2	Up to 20 ft.	¼"	¼"	8½ lb.
500	4	Up to 20 ft.	¼"	¼"	8½ lb.

Fig. 11. Sec. 9.—Geared circulating pump. Interior view.

Fig. 11, Sec. 9, shows an interior view of a B. & S. circulating pump. The following tables give the specifications of various Brown & Sharpe circulating pumps:

(B. & S.) NOS. 1 AND 3

(3 1/4-inch Pulley for No. 1. For No. 3 Pump, 5-inch Pulley)

Number	R. P. M.	Capacity quarts per minute	Height forced	Suction	Discharge
1	300	4	Up to 20 ft.	3/8"	1/4" or 3/8"
1	500	8	Up to 20 ft.	3/8"	1/4" or 3/8"
3	300	20	Up to 20 ft.	3/4"	1/2" or 3/4"
3	500	40	Up to 20 ft.	3/4"	1/2" or 3/4"

(B. & S.) NOS. 11, 12 AND 13 GEARED PUMPS.

Constant Flow With Pump Running in Either Direction. Driving Pulley for No. 11 is 3 1/2 Inches, for No. 12 is 4 1/4 Inches, for No. 13 is 5-inch Diameter.

11	300	4	Up to 20 ft.	3/8"	1/4" or 3/8"
11	500	8	Up to 20 ft.	3/8"	1/4" or 3/8"
12	300	12	Up to 20 ft.	1/2"	3/8" or 1/2"
12	500	24	Up to 20 ft.	1/2"	3/8" or 1/2"
13	300	20	Up to 20 ft.	3/4"	1/2" or 3/4"
13	500	40	Up to 20 ft.	3/4"	1/2" or 3/4"

The Richardson-Phenix rotary pumps consist of a pair of cams running together in a tight case. They have the following specifications:*

Number	R. P. M.	Gals. per minute	Suction	Discharge
No. 1	200 to 300	1/4 to 1 1/2	3/8" and 1/2"	3/8" and 1/2"
No. 2	200 to 500	2 to 5	3/4"	3/4"

* Note. Pulley 3x1 for No. 1 and 4x1 for No. 2.

SECTION 9a

LUBRICATING AND INDUSTRIAL OIL STORAGE

Manufacturing establishments which use large quantities of oil should provide a central oil storage. The oil-house should be placed in charge of a competent man, who will keep a careful and accurate account of the oils issued to the various departments of the plant. By examining the oil records monthly, and noting the increases or decreases in the amounts of oil used by the various machines, a close check may be maintained upon the efficient and economical operation of the plant, and large savings may be effected in the annual cost of lubrication.

OIL STORAGE.—For plants using oil in quantities of several barrels only at a time, the equipment as shown in Fig. 1, Sec. 9a, will suffice. The

Fig. 1. Sec. 9*a*.—Oil storage outfit made by the Gilbert & Barker Manufacturing Company.

barrels are emptied by gravity into the tanks through manholes. Measuring pumps, with non-dripping nozzles, should be provided to permit the filling of oil cans without the use of dust-collecting funnels. Fig. 2, Sec. 9a, shows the working parts of another type of outfit.

In plants where there is not enough room for oil storage in the storeroom or shop, the tanks may be placed in a separate vault underground or under the basement floor. In this case the tanks may be placed on the floor of the vault, as is shown in Fig. 3, Sec. 9a.

In case the oils are to be delivered from tank wagons or tank cars through a hose or pipe, a fill box, such as is shown in Fig. 4, Sec. 9a, set in the floor of the oil house or in the receiving platform should be used.

In plants where the oils are received in large quantities, and the area covered by the plants is large, such as shipyards, etc., a special oil car for distribution of oil from the main oil-house to the different substations is recommended.

Fig. 5, Sec. 9a, shows a neat installation of pumps and service room as used by a large railroad.

Fig. 6, Sec. 9a, shows a battery of cellar cylindrical tanks, such as would be used in connection with the equipment mentioned above.

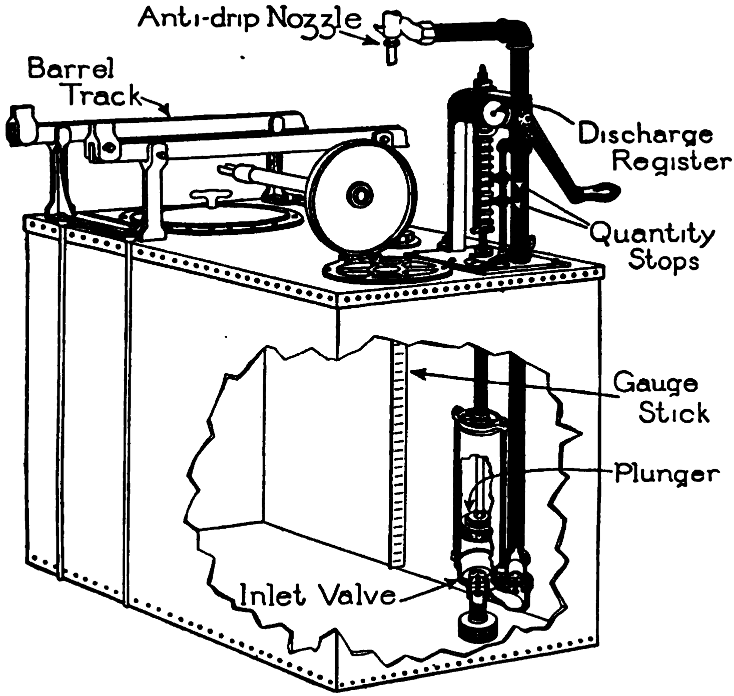


FIG. 2. SEC. 9a.—Working features of small storage outfit made by S. F. Bowser & Co.

In some plants it is desirable to provide pump delivery for oils both on the first and second floors, and in some cases on the third floors. The pump equipment shown in Fig. 7, Sec. 9a, manufactured by the Gilbert & Barker Co., is designed for this purpose.

OIL STORAGE NOTES.—All tanks for the storage of oil should be connected with a vent pipe, which is carried outside of the building and terminates above the roof. The top of this vent pipe should be equipped with a special vent fitting, as shown in Fig. 8, Sec. 9a.

Tanks for the storage of black oils, cylinder oils and other oils having a high pour test should be equipped with heating coils for the purpose of

thinning out the oils, and all pipes for carrying such oils should be laid well below the frost line.

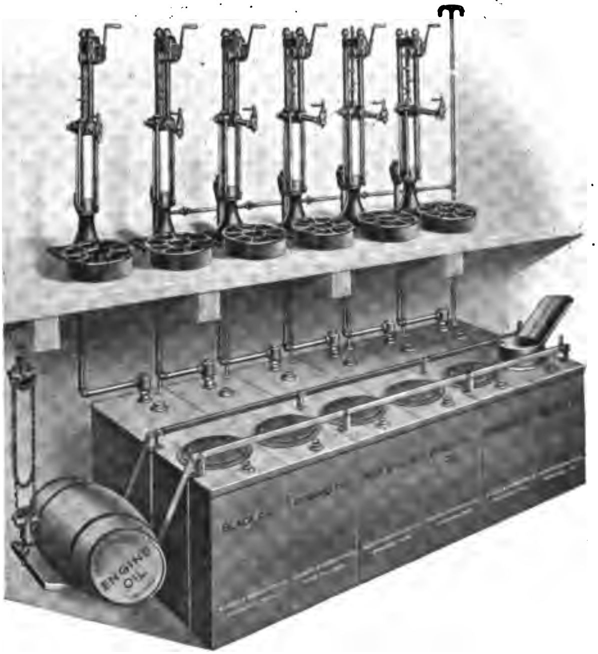


FIG. 3. SEC. 9a.—Oil storage cellar tanks and first floor pumps.

Certain liquids may affect the brass parts of the pump, or they may become discolored by it. In such cases the pumps should be specially coated. The builders of oil-handling equipment can furnish special equipment for such cases.

FIG. 4. SEC. 9a.—Fill box.

Gasoline, naphtha or benzine must always be stored in tanks that have been placed underground to a depth as specified by the local fire marshal or the fire insurance underwriters.

Tanks for the storage of volatile liquids should be of the non-evaporative type. These are designed to have access to the air only through the vent pipe, which, being of considerable height, precludes the entrance of fresh air to the tank.

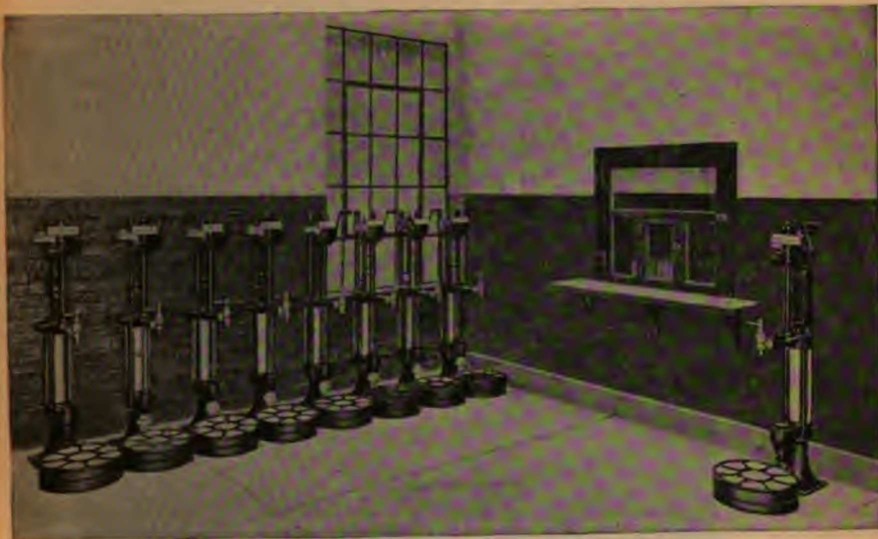


FIG. 5. SEC. 9a.—Service room pumps.

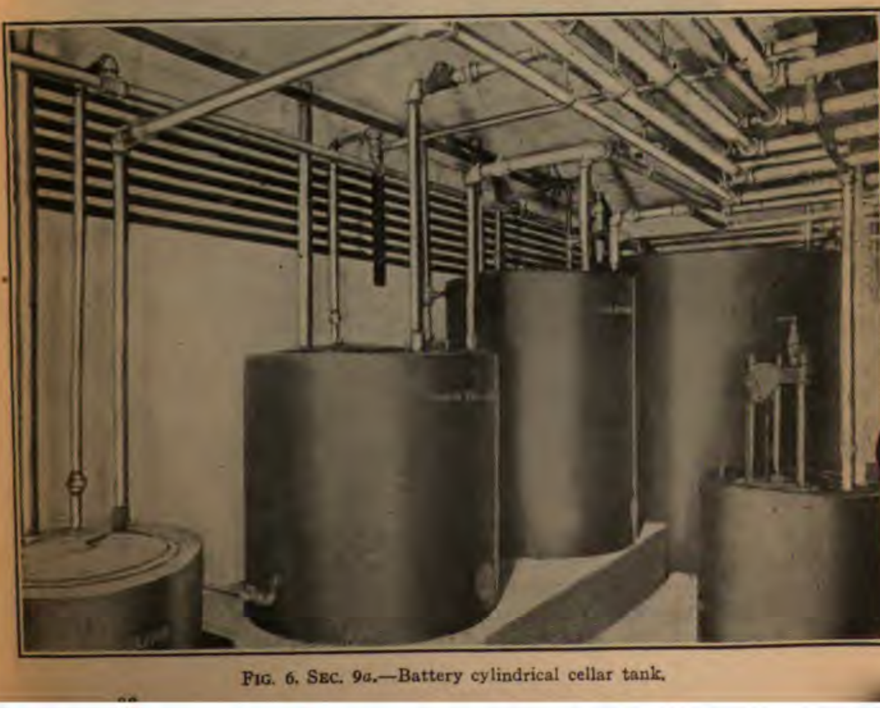


FIG. 6. SEC. 9a.—Battery cylindrical cellar tank.

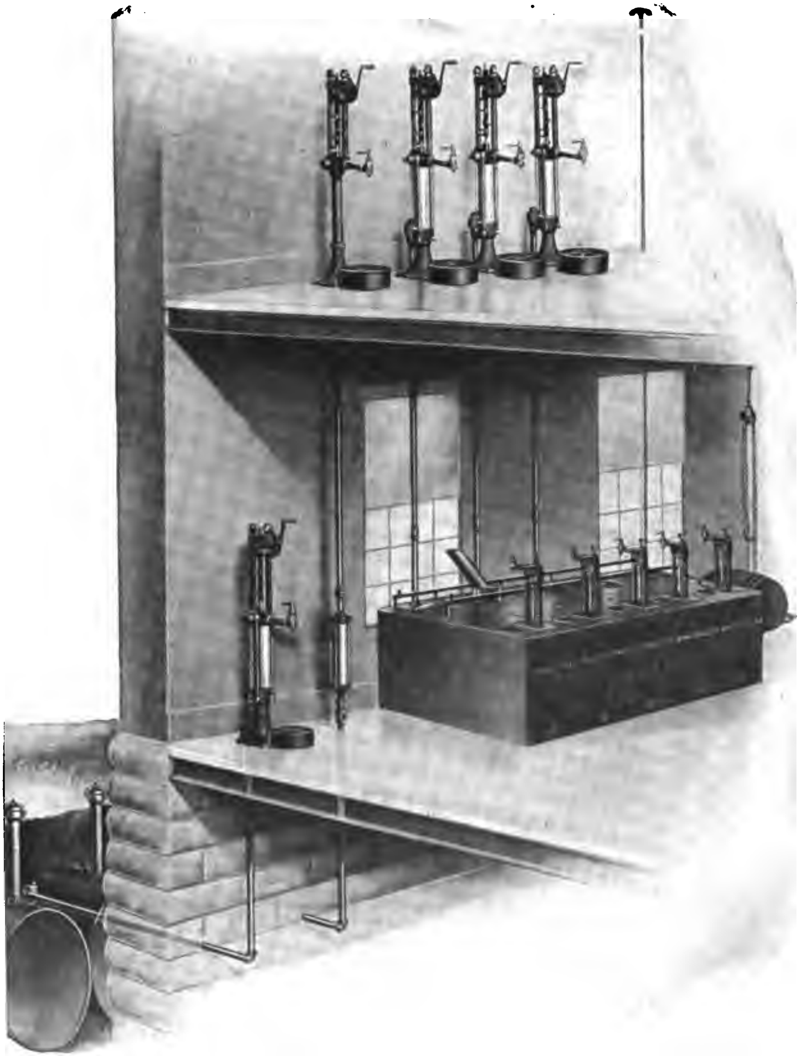


FIG. 7. SEC. 9a.—Hand operated, two floor oil handling equipment.

PLANT DISTRIBUTION OF OILS.—In the large modern plants special men are assigned to the task of distributing the oils required by the various plant departments. In this manner the distribution is systematized and a uniformity is obtained that would not be possible otherwise.

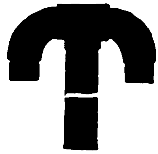


FIG. 8. SEC. 9a.—Special vent fitting.

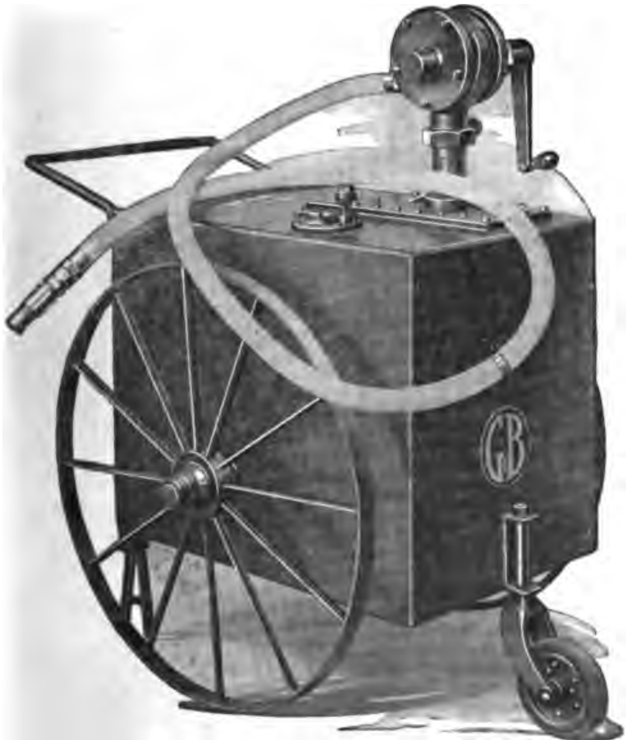


FIG. 9. SEC. 9a.—Portable oil outfit.

In some of these plants a portable outfit, such as is shown in Fig. 9, Sec. 9a, is used. This equipment is usually designed to carry 50 gallons.

In very large plants, where the consumption of oil by the various departments is large and the distance between the buildings is great, it is sometimes advisable to pipe the oil from the central storage house to the

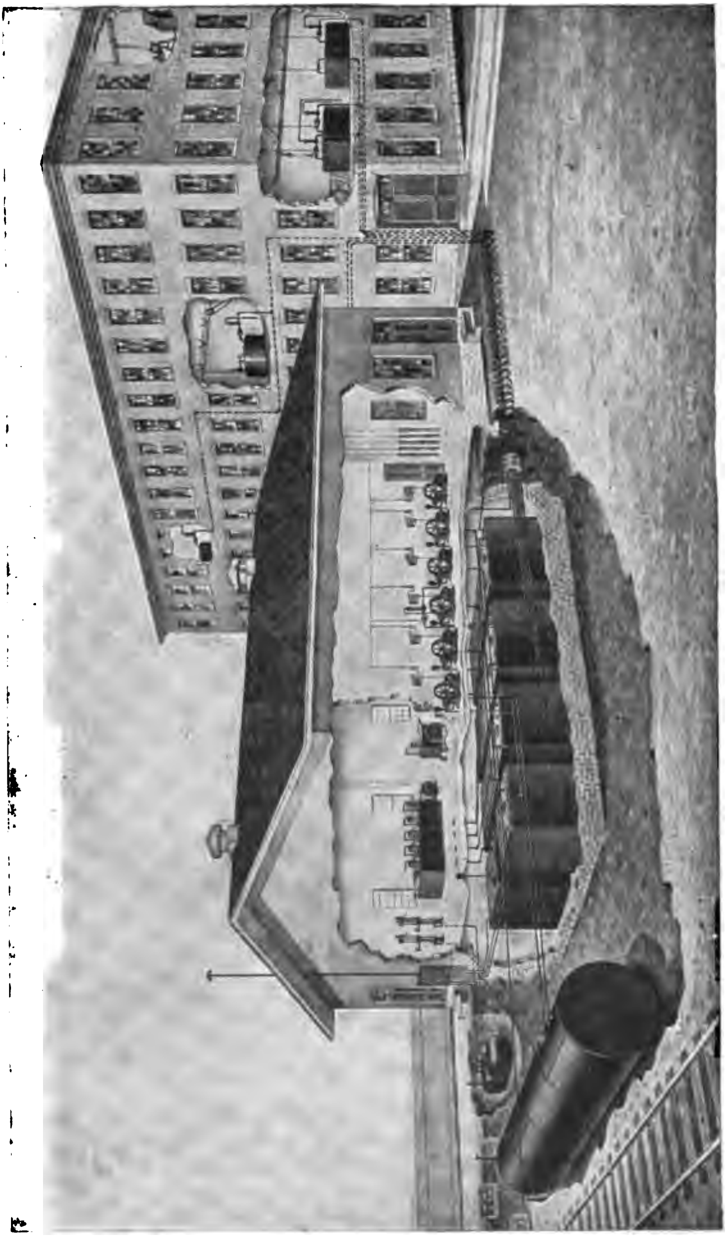


Fig. 10. Sec. 9a.—Method of delivering oil and other liquids to various floors in industrial plants.

various shops. This is usually accomplished by means of motor-driven pumps, or in some cases by steam pumps. For this plan of distribution it is recommended that flow meters be placed at the outlets in the various shops, so that a check on the consumption may be registered. In some of these installations it is necessary to install an auxiliary tank at the various shop outlets, and the oil then drawn from them through meters. (See Fig. 10, Sec. 9a. Courtesy of S. F. Bowser Co.)

EMPTY OIL-BARREL STORAGE.—A suitable storage place should be provided for empty oil barrels at the side of the oil-house.

Empty barrels should always be stacked on their bilges, with their bungs down. They should be returned at various times in carload lots to the oil company, so that credits may be received for their market value.

As deductions are made by the oil company for barrels not returned in good condition, it is advisable that care be taken not to damage the heads and staves. The bung-holes should not be bored out to an increased diameter, as that will result in "dockage."

When removing the bung use a small chisel or a bung pick, and do not try to knock the bung into the barrel, as this practice is liable to split the stave. If a vent is necessary, make it small. Never use a faucet that will not screw into a 1 1/4-inch hole.

Store empty barrels under shelter if possible to prevent the inflow of rain-water, which dissolves the glue and fouls the barrel.

OIL-HOUSES

THE DESIGN OF THE OIL-HOUSE

In large works, where the oils are received in tank cars, or where the oil is received in barrels in carload lots, the oil-house should be equipped with a railroad siding to facilitate the discharge and proper handling of the oil shipments without delays and losses.

For barrel delivery, the receiving platform should be on a level with the freight-car floor, and provision should be made in the size of the platform to receive a carload at one time. (A minimum carload consists of 65 barrels.)*

For tank-car delivery, suitable unloading pipes must be laid to a point or points near the track. It is well to locate these unloading points or outlets to one side of the receiving platform, so that freight cars containing barrel oil may be unloaded without interfering with the tank-car shipments.

If possible, the oil-house should be centrally located in the grounds of the plant, with a view towards efficient distribution of the oil.

As a suggestion in laying out an oil-house for the average large plant. the plan and elevation drawings of a well-planned building for this purpose are shown in Fig. 11, Sec. 9a.

The oils are stored in the basement as shown, and are brought up to the main floor by means of pumps provided with suitable returns for excess oil. The tanks are each connected to a vent pipe.

For filling the tanks, the oil may be brought in tank cars or barrels,

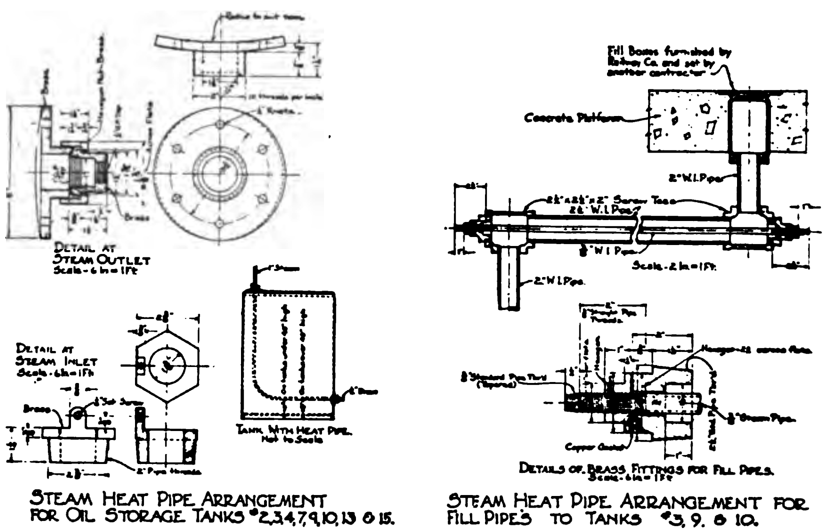


Fig. 12. Sec. 9*a*.—Railroad oil storage house. (Courtesy Phila. & Reading R. R. Co.)

* Note. At time of writing.

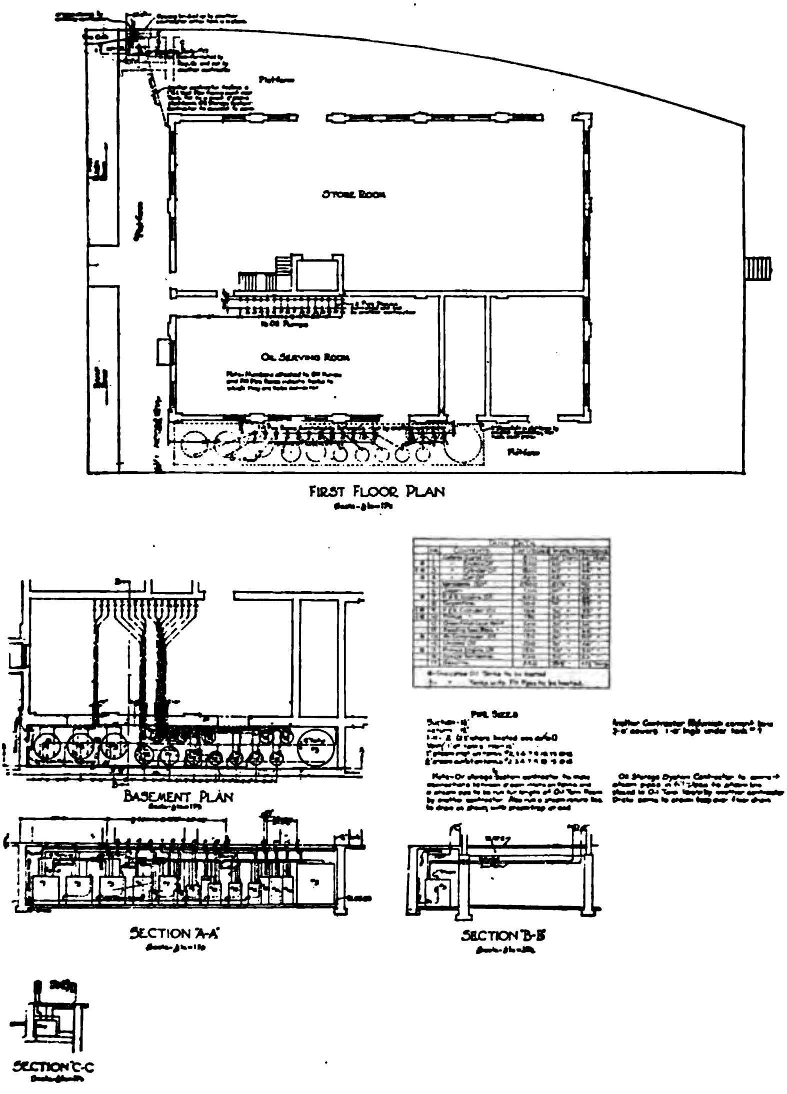


FIG. 12. SEC. 9a.—Railroad oil storage house. (Courtesy Phila. & Reading R. R. Co.)

provision being made for emptying the tank cars through pipes laid out to the middle of the track, and for emptying barrels by the use of the fill boxes on the main floor of the house.

The black oil and cylinder oil tanks are equipped with steam coils to thin the oil and aid its flow when pumped.

The unloading platform is capable of carrying 65 barrels at one time, which is a minimum carload.

Platform scales are placed at the entrance, to check all barrel deliveries, and a suitable sample case is located in the office, in which samples of the incoming shipments may be kept for reference purposes.

The house should be constructed as nearly fireproof as possible, and the ventilators in the roof kept in good working condition.

The tanks should be connected to a vent, as shown.

RAILROAD OIL STORAGE.—The oil storage system which is shown in Fig. 12, Sec. 9a, is of the latest type for railroad use. It was designed for use by the Philadelphia and Reading Railway.

The details given are in line with modern practice.

OIL-HOUSE RECORDS AND COSTS.—The various departments of a plant should be charged with the amounts of the different oils used.

When a man requisitions oil from the oil-house, a slip should be filled out, showing the grade and the amount of the oil issued and the man and department getting it. A specimen slip, which may be used as a guide, is shown below:

Oil-house Requisition Slip

DATE..........	DEPARTMENT..................
HOUR..........	
NAME OF OIL........................	Gallons............
NAME OF OIL........................	Gallons............
NAME OF OIL........................	Gallons............
NAME OF GREASE.....................	Pounds............
FOREMAN:	Issued to..........

At the end of the day or week, as desired, a report may be prepared upon a suitable form by the oil-house man, showing exactly the total gallonage of oils and poundage of greases that have been issued to the various shops and the stock remaining on hand. Four carbon copies of this report should be made. One copy is sent to the purchasing agent, so that he may be advised when and how often to order. One copy should be sent to the accounting office, so that a record of deliveries may be had, giving the time and amounts, which will aid this office in properly checking the oil company bills. One copy should be sent to the general manager's office, so that his office may keep an exact record of the cost of lubrication of the plant and may also note the relative amounts of oils used by the different shops, with a view to correcting any apparent waste.

The report should include a suitable record of deliveries and number of empty barrels returned to the oil company, so that the stock on hand may be clearly indicated. The sample report given below is included as a suggestion to those desiring to install a similar system to that described above. The weight method of checking deliveries from the oil company should be used in all cases, and is described in another section of this book.

(SPECIMEN REPORT)

Weekly Oil-house Report of the Eureka Shipbuilding Company

Date From.............. Date To ....

Name of oil or grease	Issued to								
	Yard	Machine shop No. 1	Machine shop No. 2	Power house No. 1	Power house No. 2	Auto trucks	Cranes	Tool house	Total
Cylinder oil, No. 1	..	...	...	75	65	...	..	..	140
Cylinder oil, No. 2	..	...	...	53	..	...	..	90	143
Machine oil, No. 1	..	157	235	75	56	...	..	..	523
Machine oil, No. 2	..	67	35	25	35	...	20	50	212
Black oil	35	10	...	..	..	...	65	..	110
Motor cylinder oil	..	...	...	..	..	38	..	..	38
Gasoline	75	...	...	..	..	175	..	35	285
300° mineral seal oil	30	...	...	..	..	...	..	..	30
150° burning oil	64	...	...	..	..	...	..	25	89
Cup grease	..	10#	25#	..	10#	...	5#	..	50#
Gear grease	25#	...	25#	..	..	...	10#	..	60#

Stock Record

Name of product	On hand at beginning week	Used during week	Received during week	Stock on hand
Cylinder oil, No. 1	235	140	154	249
Cylinder oil, No. 2	258	143	152	267
Machine oil, No. 1	650	523	750	877
Machine oil, No. 2	365	212	357	510
Black oil	150	110	250	290
Motor cylinder oil	75	38	...	37
Cup grease	147#	50#	...	97#
Gear grease	75#	60#	378#	393#
300° mineral seal oil	75	30	...	45
150° burning oil	175	89	50	136
Gasoline	575	285	250	540

Empty Barrels Returned for Credit

Kind of barrels	Number	Date returned	Credits at current prices	Totals
Refineds	8	1/17	$1.05	$8.40
Machine, motor oil and cylinder oil barrels	26	1/17	0.95	24.90
Black oil barrels	5	1/17	0.85	4.25

Report signed by ....

DELIVERY FORMS.—The following form is suggested for use as a record of delivery of oils to the oil-house in barrels when the weight method is used for checking gallonages:

Delivery Form

BRAND............. DATE DELIVERED.......... DATE TESTED.............
WEIGHT BARREL AND OIL ....(gross weight). GRAVITY....AT....(—) FAHR.
WEIGHT BARREL ....(tare weight). CORRECTED GRAVITY....AT 60° FAHR.
NET WEIGHT OIL ....(pounds). WEIGHT PER GALLON......AT 60° FAHR.

$$\frac{\text{WEIGHT OIL}}{\text{WEIGHT PER GALLON}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{GALLONS OIL DELIVERED.}$$

................GALLONS BILLED BY OIL COMPANY.
................GALLONS ADJUSTMENT.

CHECKED BY ....

The above form can be gotten up as a small and compact pad, so that the checker can take down the readings direct as he checks the delivery.

SPECIAL EQUIPMENT

Fig. 13, Sec. 9a, shows a Folding Barrel Skid and Drainer made by the Gilbert & Barker Manufacturing Company. It provides an easy and effective method of emptying oil barrels by gravity, which is the method that gives the best results. If the oil is heavy, it is impossible to thoroughly drain the barrel by pumping out the oil, and usually a waste results, due to oil remaining in considerable quantities on the insides of the barrels.

PORTABLE CUTTING OIL OUTFITS.—Fig. 14, Sec. 9a, shows a portable cutting oil outfit, as manufactured by Gilbert & Barker Company.

FIG. 13. SEC. 9*a*.—Folding barrel skid and drainer.

This equipment has a rotary pump that can be turned in either direction, either for drawing oil into the tank or for pumping the oil out.

With this equipment the machines are not permitted to remain idle while the workmen go for fresh oil to the main storage. The dirty oil may also be recovered and pushed to the filter, emptied and reclaimed.

WASTE SATURATING AND DRAINAGE TANKS.—Fig. 15, Sec. 9a, shows a waste saturating and drainage tank, equipped with a screen for draining the waste.

FIG. 14. SEC. 9a—Portable cutting oil outfit for a machine shop.

FIG. 15. SEC. 9a.—Waste saturating and drawing tank.

CONCRETE STORAGE TANKS.—(Proceedings American Soc. of C. E., Aug., 1915; reprint in "Concrete Tanks for Oil Conservation," Portland Cement Association): "Concrete properly proportioned is impermeable to oils of low gravity under the heads of 18 to 24 feet. This is proven by the inspection of concrete in reservoirs which have been standing full for two years. A scratch with the penknife removed the scum of oil from the surface of the lining and showed concrete white and unattacked in a number of places."

Concrete tanks are also used successfully to store the lighter oils, but in such cases are usually treated with some preparation to increase the density of the inside concrete surface.

"Successful storage of oil requires, among other things, that the containers prevent loss through seepage and evaporation, and that the fullest measure of protection against fire be secured. The desired ends are more nearly attained through underground storage than otherwise, the tanks being so constructed that they can be roofed and finally covered with a foot or more of earth. Concrete tanks meet these requirements. It is necessary to maintain the oils at as nearly even temperature as possible, regardless of seasonal changes. This keeps evaporation losses at a minimum.

"In the storage of heavy oils the container should be so constructed that during extreme cold weather the oil will not become congealed, making it difficult to draw from the tanks. This has sometimes been accomplished by installing a system of piping on the floor of the tank, into which the steam could be turned to warm the tank contents."

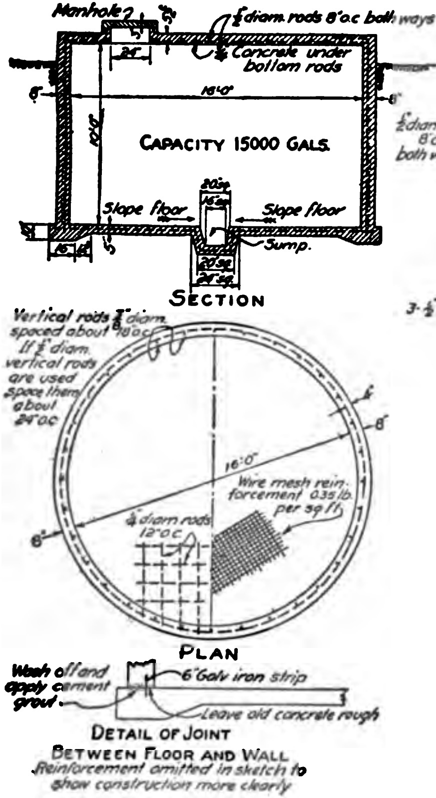
Fig. 16, Sec. 9a, shows a design for a small concrete oil-storage tank, from "Concrete Tanks for Oil Conservation," which states:

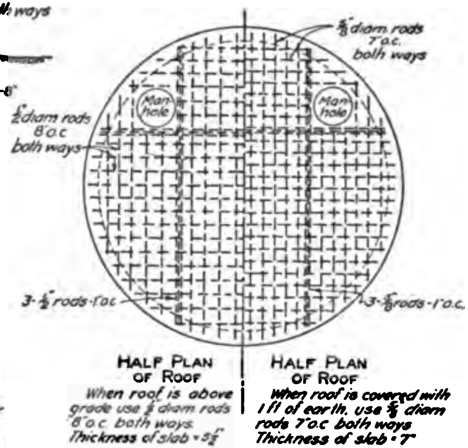
"One important detail of concrete construction which is frequently overlooked to the detriment of the finished structure is proper protection of the concrete during hardening. Unless the concrete is prevented from drying out too rapidly the tank will be porous, if not considerably weakened.

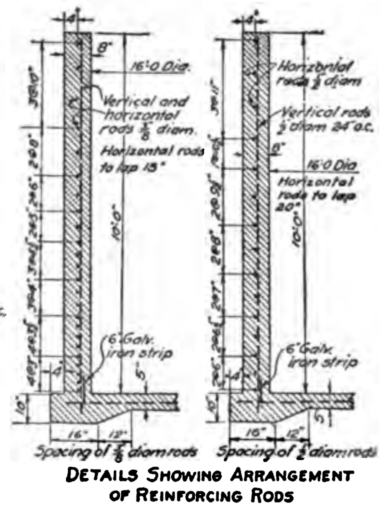
"When concreting is done in cold weather the work should be protected against freezing for at least 48 hours or until sufficiently hardened to be proof against injury from freezing temperature. In hot weather the concrete should be protected from the direct rays of the sun and from drying winds, being wet down from time to time to secure this protection. Additional advantage results from filling the tank with water as soon as the concrete has acquired sufficient strength to withstand the pressure.

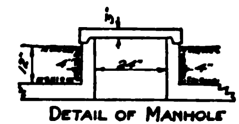
"Surface treatment to be given the concrete to prevent seepage of lighter oils depends entirely upon the gravity of the oil to be stored. Well-made, properly placed concrete is impermeable to the heavier types of oil, such as fuel and crude oil, without any special treatment beyond perhaps a coating of rich cement mortar applied immediately after the forms have been removed. This should be well worked into the surface with a wood hand float, and then lightly troweled. Several applications of a solution of sodium silicate are sometimes used. This treatment results in insoluble compounds being formed in the surface concrete by chemical reaction of the silicate of soda with free alkalies in the cement."

(Bulletin 155, Bureau of Mines, U. S. Department of Interior): "In connection with the use of underground concrete tanks for the storage of oil, it is interesting to note that the El Paso and Southwestern Rail-









QUANTITIES OF MATERIALS REQUIRED FOR 16'-0" DIAM. TANK 10'-0" DEEP

CONCRETE 22½ CU. YD. MIX = 1:2:3

	Cement sacks	Sand cu. yd.	Stone cu. yd.	Reinforcement
5½" Roof slab	28	2	3¾	½" rods = 478#
Floor	39	3	4½	¼" rods = 67.7 lb. or wire mesh 42" wide = 84.5 lb.
Walls	91	6¾	10¼	⅜" rods = 663 lb. or ½" rods = 705 lb.
For 7" Roof Slab use these quantities	36	2¼	4½	⅝" rods = 625 lb.

FIG. 16. SEC. 9a.—15,000 gallon concrete oil storage tank.

road Company, at various places along its system has for the past five years been storing fuel oil of 24° to 38° Be. in circular concrete tanks about 12 feet in diameter by 6 feet deep. The bottoms of these tanks are 8 inches thick and the sides 6 inches thick, and each tank is covered by a concrete roof. The proportion of the mix is 1:2:4 and the largest rock is 1 inch. The aggregate is thoroughly mixed, and care is taken that when it is placed in the forms it is well tamped and all air bubbles thoroughly worked out, so as to insure as dense a concrete as possible.

"Tanks that have been in use five years have been examined inside and out, but no signs of leakage were discovered. At present the company has 12 such tanks, and their adaptability to oil storage has proved so satisfactory that more are in process of construction. No oil or waterproofing compounds are used.

"A local company at San Antonio, Tex., has three such tanks, but of much greater capacity (180,000 to 400,000 gallons), in which oils ranging in gravity from 15° to 30° Be. have been stored. One of these tanks has been in use 12 years. It was emptied recently and examined inside and out, but no signs of leakage were found. The mix, as for the El Paso tanks, is 1:2:4, and the coarsest aggregate 1-inch rock. At present a fourth tank is being constructed. This will have a diameter of 61 feet 6 inches, a depth of 18 feet and a capacity of about 400,000 gallons. The bottom will be 17 inches thick and the sides 2 feet at the bottom, tapering to 1 foot at the top; all heavily reinforced with steel rods. No oil-proofing compounds are used in any of these tanks.

"A local electric company at St. Helena, Calif., built a rectangular reinforced concrete tank in 1911. This tank is 16 feet long, 14 feet wide and 5 1/2 feet deep, having a capacity of approximately 10,000 gallons. The bottom is 20 inches thick and the sides 8 inches at the bottom, tapering to 5 inches at the top. Both the sides and the bottom were reinforced with steel rods. At the time the tank was constructed it was coated inside with a solution of sodium silicate. However, after 18 months of service the coating had become practically useless. The tank at this time was examined inside and outside by digging pits, but as no leakage was found no further attempt at oil-proofing was made. Since that time the tank has been continually in service for the storage of oil varying in gravity from 15° to 26° Be. The roof of this tank is made of wood, covered with roofing paper. As a means of lessening evaporation losses and providing a run-off for rain-water, as the wooden roof is practically flat, a second corrugated iron roof of proper pitch has been constructed about 3 feet above the first roof, allowing free circulation of air between the two."

SECTION 10

INDUSTRIAL PRACTICE

UTILIZATION LUBRICATING AND INDUSTRIAL OILS

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
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6				
7				
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9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
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SECTION 10a
ARTILLERY AND ORDNANCE

RECOIL CYLINDER OIL, FOR GUN CARRIAGES.—(Committee on Standardization of Petroleum Specifications, April, 1920): The following specifications cover a product referred to in the Government specifications as Hydroline Oil:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies to fill the recoil cylinders of gun carriages. 2. The oil must be entirely neutral and free from acid or alkali, free from ash and saponifiable oil. PROPERTIES AND TESTS: 3. Viscosity: The viscosity shall be not greater than 145 seconds at 32° F., not less than 43 seconds at 100° F. 4. Pour Test: The pour test must be below 0° F. 5. Evaporation Test: The oil must not lose more than 5 per cent. in weight when heated at 212° F. for two hours. Preference will be given to oil having the lowest per cent. in weight, other things being equal. 6. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

75 AND 155 MM. GUN CARRIAGE (FRENCH), OIL AND GREASE FOR RECOIL MECHANISM.—(Committee on Standardization of Petroleum Specifications Report, April, 1920): 1. This specification covers the grade of petroleum oil and grease used by the United States Government and its agencies for the recoil mechanism of 75 and 155 mm. French gun carriages. RECUPERATOR OIL: 2. This oil shall be a highly refined petroleum product, free from animal or vegetable oils. PROPERTIES AND TESTS: 3. Flash Point: The flash point shall not be lower than 345° F. 4. Viscosity: The viscosity at 100° F. shall be within the following limits: 385 to 430 seconds. 5. Pour Test: The pour test shall be 5 or more degrees below zero F. 6. Acidity: Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil. 7. Corrosion: A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature. RECUPERATOR GREASE: 8. The grease must be a well-manufactured product composed of a calcium soap and a highly refined mineral oil. PROPERTIES AND TESTS: 9. The mineral oil used in reducing the soap must have a viscosity at 100° F. of not less than 180 seconds. 10. Soap Base: The grease shall contain approximately 18 per cent. of a calcium soap made from a whole fat such as pure tallow oil, neatsfoot oil, lard oil, horse oil, or other pure animal oils used singly or in combination. 11. Consistency: This grease must be similar in consistency to the approved trade standard for No. 3 grease. 12. Moisture: The grease must be a boiled grease containing not less than 1 per cent. nor more than 3 per cent. of water when finished. 13. Corrosion: A clean copper plate must not be discolored when submerged in the grease for 24 hours at room temperature. 14. Ash: The ash shall not be greater than 2.3 per cent. 15. Fillers: The grease shall contain no fillers, such as resin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler. 16. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

NOTE. See index for lubricants for small arms and howitzer buffer oil, etc.

SECTION 10b

AIR COMPRESSORS

AIR COMPRESSORS AND THEIR LUBRICATION

Air compressors are usually of the single-cylinder, or of the two-cylinder, two-stage type. In the single-cylinder type, the air is compressed to the full desired degree of compression in one cylinder, while in the two-stage type the compression of the air is broken. In the latter type it is usually compressed to 40 or 50 pounds per square inch in one cylinder, and then it is passed through an intercooler, where its temperature is reduced before the compression occurs in the second cylinder, in which cylinder the compression is completed.

The series of operations described for the two-stage compressor may be also carried out in further detail in the three- and four-stage compressors, the air being compressed a small amount in each cylinder and then cooled and further compressed in the next.

TABLES OF TEMPERATURES.—When air is compressed, the work which is consumed in the compression is converted into heat and is evidenced by the rise in temperature of the compressed air. This rise in temperature of the air follows a definite law, and the theoretical temperatures can thus be tabulated.

This table gives the final temperature in the cylinder at the end of the compression stroke for single stage, also for two-stage (or compound) compression, when the free air entering the cylinder is 60° F.

CYLINDER TEMPERATURES AT END OF PISTON STROKE

Air Compressed to lbs. Gauge	Final Temp. Single Stage	Final Temp. Two Stage
10	145 F.	......
20	207 F.	......
30	255 F.	......
40	302 F.	......
50	339 F.	188 F.
60	375 F.	203 F.
70	405 F.	214 F.
80	432 F.	224 F.
90	459 F.	234 F.
100	485 F.	243 F.
110	507 F.	250 F.
120	529 F.	257 F.
130	550 F.	265 F.
140	570 F.	272 F.
150	589 F.	279 F.
200	672 F.	309 F.
250	749 F.	331 F.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
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Variations from these temperatures will occur in actual practice, due to water-jacketed air cylinders and radiation, tending to lower the temperature at the higher pressures. But at, say, 50 pounds pressure and lower, the heat is likely to be somewhat greater than given by the table, particularly if the compressor is run at high speed, and also if it is not water-jacketed.

The heads and cylinders of compressors are usually water-jacketed, in order to prevent the compression heat from becoming excessive, which would reduce the economy of operation of the machine.

The use of intercoolers also reduces the heat of compression retained in the air. Therefore, the temperatures given in the table are not actually met with in practice, but may serve as a guide to the mechanical and physical conditions that are met with in air-compressor lubrication.

AIR-COMPRESSOR EXPLOSIONS.—Poor working conditions in a compressor, involving leaky valves, hot and dirty inlet air, insufficient cooling water, carbon deposits in cylinders, tend to produce high and dangerous compressed-air temperatures, which are sufficient to ignite too volatile constituents of lubricating oil and cause explosions.

The Massachusetts Boiler Board gives following recommendations:

(*a*) Keep the temperature of the compressed air during compression as low as possible.

(*b*) Keep the piston tight and in good working condition.

(*c*) Take the inlet air from as cool and clean a location as possible.

(*d*) Use plenty of cold water, from a source that is not liable to fail, and have it visible at discharge from cylinders or coolers.

(*e*) Do not use kerosene or other volatile substances in the cylinders, tanks or other connections.

(*f*) Use mechanical or sight-feed oilers for the compressor cylinder.

(*g*) Use the least amount practical of the best air-cylinder oil. Air cylinders require much less oil than steam cylinders.

(*h*) Keep the cylinders, tanks and connections as free from carbon, accumulated oil and deposits as possible.

(*i*) A good cylinder oil is one which lubricates well, leaves little or no deposit, is the least volatile at high temperatures and has a high flash-point.

* **LUBRICATION OF AIR CYLINDERS.**—The lubricating requirements of air-compressor cylinders differ from the lubricating requirements of steam-engine cylinders, in that there is no moisture present. There is the intense dry heat of compression to be dealt with, however, and this heat has a tendency to reduce the body of the lubricant and to vaporize it.

For compressions up to 125 pounds per square inch, an oil having the following approximate specifications is recommended: (270 Vis. at 100° Fahr. and 420° Fahr. flash, P. B.) (350 Vis. at 100° Fahr. and 375 or more flash, A. B.). Air-compressor oil must have a good evaporation test and should be filtered. For high pressures, an oil having the following characteristics should be used: (320 Vis. at 100° Fahr. and a flash test of 525 or over, P. B.) (750 Vis. at 100° Fahr. A. B.).

CARBONIZATION.—Carbonization of the oil allows the accumulation of deposits of carbon, which are sticky in the early stages of their formation, but hard and flinty later. Such deposits accumulate on the cylinder valves, in the cylinder passages, in the pipes and eventually in the air receiver.

Sticking or partial closing of the valves and their consequent failure to act properly is probably the chief objection to this action from the standpoint of the efficient operation of the compressor.

The formation of excessive carbon deposits is apt to be due to any one or more of the following causes:

1. The ill-advised use of some oil, such as a steam cylinder oil, which on exposure to the heat of the air cylinder, gives a tarry deposit.

2. The use of oils of too great a viscosity—commonly referred to as "too heavy oils." These do not atomize readily, and, therefore, remain too long upon the hot cylinder walls, etc., thus baking down to sticky carbon deposits.

3. The use of too great quantities of oil, which has the same effect as the use of too heavy an oil, as far as the carbonization is concerned.

The failure to provide a proper screen over the air intake of the compressor, thus allowing free entrance of dangerous dust (especially coal dust).

The objections to this carbonization aside from the sticking of air valves and choking of the air passages is the menace of fire entailed by carbon deposits. Carbon particles torn loose from them may become incandescent from causes which could not be anticipated by the compressor manufacturer. If such incandescent carbon particles should happen to come in contact with "oil vapor" given off by the lubricating oil, a fire might possibly be started whose menace would be small or large, depending upon how much carbon had been allowed to accumulate in the compressor and piping to the receiver. If these are kept properly cleansed at all times, there should never be any danger.

PARAFFIN AND ASPHALT OILS.—From a strictly operating standpoint—so it is claimed by some lubricant manufacturers—there is no distinction between the two classes of lubricants as to their desira-

* Note. It is sometimes desirable to compound a compressor oil with about 3 per cent. elaine. A typical formula being 65 per cent. filtered spindle, 32 per cent. cold test cylinder stock, 3 per cent. elaine.

bility as compressor cylinder oils, provided that both have been properly filtered in the process of manufacture to remove the "carbon-forming" elements. If any carbon should be formed, however, such carbon deposited by the asphaltic-base oils is of a light fluffy nature and easily cleaned out, whereas that deposited by paraffin-base oil is very adhesive, and characterized by the hard, flinty nature.

LUBRICATION NOTES.—The cylinders and valve chests of air compressors must be sufficiently cooled to avoid explosions due to air that may be carbureted with oil.

A striking illustration of the effect of the heat of compression of air is shown in the Diesel Motor, where air is compressed to about 450 pounds per square inch and is then hot enough to ignite an atomized charge of oil.

Air-compressor oils must be straight mineral oils and must not be too high in viscosity. They should be examined as to the nature and amount of the residue left after evaporation.

For compression temperatures of 350° Fahr. to 400° Fahr. the oil used should not flash below 500° Fahr., and where the temperature does not exceed 300° Fahr. an oil of not lower than 375° Fahr. may be used.

When feeding lubricating oil to air-compressor cylinders, care must be taken not to feed an excess of the oil, which will result in gumming and carbon-forming deposits.

Dusty and impure air, if supplied to compressor cylinders, is often the cause of cylinder deposits. The location of the air inlet should always be first examined when adjusting a compressor complaint.

Most cases of air-compressor complaints come from the users of small, single-stage machines, and the trouble is usually due to excessive temperatures, caused by forcing the machines. Compressors having mechanically operated valves require more oil, but cause less trouble than compressors having spring valves. Trouble with multi-stage compressors is not usual. The air in these machines rarely ever attains an extremely high temperature, unless the cooling water system becomes deranged.

RECEIVER PIPES.—The "receiver" and pipes into which the compressor discharges should be blown out regularly, to remove any oil and water that may have accumulated there.

DISCHARGE VALVES.—The discharge valves should be regularly inspected. Often cases have been investigated where the discharge valves have stuck and admitted hot compressed air back from the receiver into the cylinder. The resulting increased temperature of the air before compression starts causes it to reach the flash-point of the cylinder lubricating oil during compression.

LUBRICATORS.—Always close the lubricators immediately before the compressor is shut down.

OIL FEED.—Reduce the amount of oil feed to the compressor cylinder to a minimum. An excess of oil, as before stated, not only causes carbonizing troubles, but offers a sticky resting place for dust entering with the air, thus causing cylinder and exhaust-valve troubles.

CYLINDER DEPOSITS.—Cylinder deposits may be removed by feeding ordinary soapsuds through the regular oil-cup hole for several hours while the machine is running. Before the machine is shut down stop feeding the soapsuds and commence feeding oil, to avoid rusting.

Another method other than soapsuds for cleaning an air compressor system, for cleaning the air receiver and piping, may consist of a pound of lye to 18 pounds of water. This mixture should be passed into the discharge line at 65 to 75 drops per minute while the compressor is running.

The soapsuds for removing carbon should consist of 1 part soft soap to 15 parts of water.

EXPLOSIONS IN AIR COMPRESSORS.—Some air-compressor explosions have been due to the failure to watch the water side of the intercooler and water-jackets, and to keep them free from all dust, mud and other foreign substances, thus permitting them to become inefficient.

STEAM-DRIVEN COMPRESSORS.—Usually in this type the main bearings, cross-head pins, guides and crank-pins are lubricated by splash feed. The crank-case is filled with oil up to a point which will allow the crank discs to dip into the oil a small distance.

GROANING OF VALVES.—This is a common trouble and is usually due to faulty fitting of the piston rings, which, due to alternating pressures, commence to vibrate, increasing the vibration of the rings, and groaning results.

The groaning can sometimes be stopped by increasing the viscosity of the oil used.

INTRODUCTION OF LUBRICANT.—Usually the air-cylinder oil is introduced at or above the points of air intake.

In some very large air compressors, such as the "blowing engine" type, the oil is introduced at several points at the top and side of the cylinder.

Greatly improved results will be obtained with automatic lubricators. The lubrication of steam-driven compressors may be simplified by using a two-compartment lubricator, so that the steam side can be fed from one compartment and the air cylinder from the other.

VALVE STICKING.—Excessive supply of oil is one of the most frequent causes of air-cylinder troubles. It causes gumming and valve sticking, which will allow the hot compressed air to flow back into the cylinder.

The discharge pipe should be frequently blown out, as well as the receiver, to remove any sediment, oil or water that may have accumulated in them.

COMPRESSOR NOTES

CROSS-COMPOUND COMPRESSORS.—Fig. 1, Sec. 10a, shows outside and sectional views of a Westinghouse 10 1/2-inch Cross-compound Compressor, such as is used in contracting and industrial service. It will be found in use for operating boiler-tube cleaners, deep-well pumping, blowing out electrical machinery, operating pneumatic tools and as part of steam-shovel equipments.

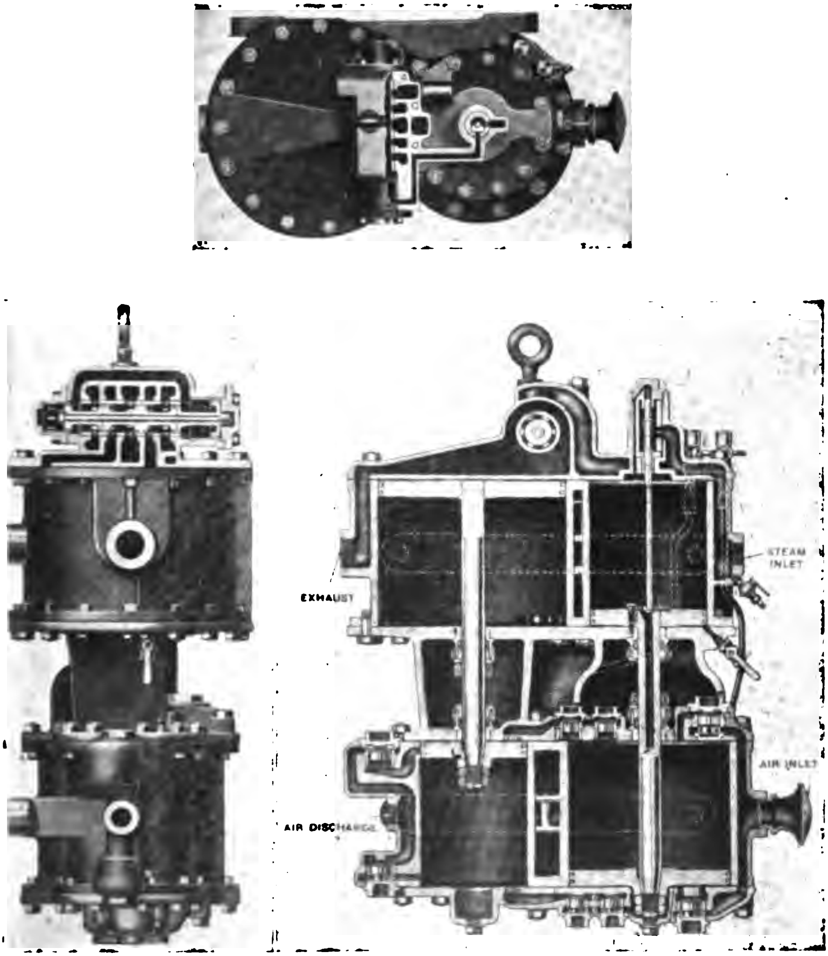

Fig. 1. Sec. 10a.—Cross compound compressor in industrial service.

LAIDLAW FEATHER VALVE AIR COMPRESSOR.—The lubricating system of this compressor is of the inclosed crank-case type. The crank-pit of the frame forms the oil reservoir, into which the crank dips. The oil is splashed over the working parts, so that the bearings are flooded and the excess oil drains back into the crank-case. The oil level in the crank-case should be inspected daily.

An intermediate head is provided between the frame oil reservoir and the cylinder-head stuffing-box. The chamber thus formed in the frame guide is provided with a drain. This is done to prevent the condensed steam from the stuffing-box of the steam cylinder from mixing with the oil in the reservoir.

The air end of the compressor is fitted with the Laidlaw Feather Air Valve. This valve is very light and flexible, and there is only one moving part—the valve strip. A curved valve guard allows the valve to rise free from the seat for the passage of air. In its operation the valve requires no lubrication. The valve is so designed that there is no valve impact, and thus a much lighter valve can be used.

COMPRESSED OXYGEN.—Holde and Muller, p. 94, "Examination Hydrocarbon Oils," 1915, state:

"In the preparation of liquid oxygen from an aqueous solution, glycerin is used * * * for lubrication, * * * since oils in contact with the compressed oxygen would instantly burn, probably explosively."

CARBON DIOXIDE.—Glycerin has been found satisfactory as a lubricant in compression machinery for carbon dioxide gas.

LIQUID AIR.—For liquid-air machines, very low boiling-point naphthas are used.

QUANTITY OF OIL REQUIRED.—The quantity of lubricating oil to feed to the air cylinders of compressors cannot be stated in exact terms, due to the varying viscosity of different oils, the heat of compression and the size of cylinder. It may be stated in general, however, that after the cylinders have acquired smooth and polished surfaces, the quantity should be reduced to the lowest limit to avoid the possibility of the accumulation of carbon and sooty deposits within the system, due to excessive use.

The basis of quantity given in Table No. 1 is recommended, subject to above modifications for these cylinders or equivalent sizes, operating under normal conditions.

It will, of course, be carefully noted and clearly understood that the results in the last column of Table No. 1 are based upon the assumption that under average conditions of temperature and usual range of oil viscosities, a pint of oil will contain an average of about 16,000 drops.* It is, of course, understood that these figures are offered merely as an approximate guide, and that every individual must exercise his own judgment in modifying them wherever his own particular set of working conditions is unusual.

TABLE No. 1

QUANTITY OF AIR-CYLINDER LUBRICANT REQUIRED PER TEN-HOUR DAY †

Diameter of cylinder inches	Size of cylinder inches	Drop oil per minute	No. pints oil required per 10 hours
8	8 x 8	1	.0375
12	12 x 12	2	.0750
18	18 x 18	4	.1500
24	24 x 24	6	.2250
30	30 x 30	8	.3000
36	36 x 36	10	.3750
42	42 x 42	12	.4500

* This figure is subject to considerable variation, according to the type of oil, its viscosity, etc.

† Figures of last column are based upon an estimated 16,000 drops per pint of oil at 75° F.

SECTION 10c

AVIATION ENGINES

TYPES OF ENGINES.—There are several main divisions of design of aviation engines:

(*a*)

Radial and star shape arrangement of cylinders, such as:

1. The Anzani. } Air cooled.
2. R. E. P. }
3. Salmson. } Water cooled.
4. Canton and Unné }

(*b*)

Rotary cylinders and crank-case, with stationary crank-shaft, such as:

1. The Gnome.
2. The Le Rhone.
3. The Clerget.

(*c*)

Vertical and Vee type, such as:

1. Duesenberg.
2. Hall Scott (4).
3. Wisconsin.
4. Mercedes.
5. Hall Scott (6).
6. Benz.
7. Liberty.
8. Curtiss.
9. Renault.
10. Thomas-Morse.
11. Sunbeam.
12. Sturtevant.

ANZANI MOTOR.—Three cylinders, Y-form engine, with power stroke equal intervals of 240° of crank-shaft rotation. Cylinders and pistons of cast iron. Cooling flanges on cylinders. These engines are made with 3 and 6 cylinders and in 10- and 20-cylinder forms.

CANTON AND UNNÉ ENGINE.—Sometimes known as Salmson, 9-cylinder, water-cooled, radial engine. All 9 connecting rods have common crank-pin. Ball bearings throughout. Nickel-steel cylinders. Machined all over. Spun copper corrugated water-jackets, nickel-steel valves.

THE GNOME ENGINE.—Cylinders mounted radially about a circular crank-case. Crank-shaft fixed and crank-case revolves about it. Fig. 1, Sec. 10c, shows a Gnome motor.

Lubricating oil and gas, very rich mixture, admitted through fixed hollow crank-shaft. They are passed into explosion chamber through

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH °F.	FIRE °F.	SAYBOLT VIS: @ 100° F.	SAYBOLT V.S: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

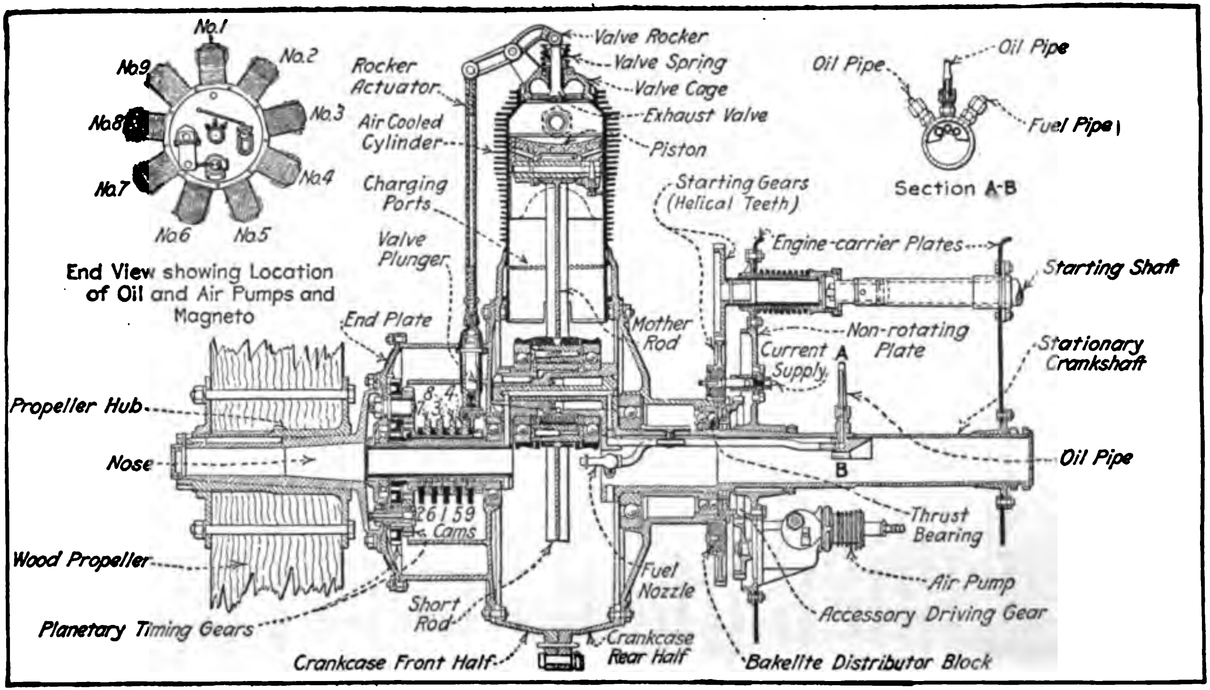

Fig. 1. Sec. 10c.—Sectional view showing construction of General Vehicle Co. Gnome Engine. (By permission from Aviation Engines, by Victor W. Page; N. W. Henley Pub. Co.)

automatic intake valve in piston head in early types, and the spent gases exhausted through a mechanically operated valve in the cylinder-head. Latest type is called "Monosoupape," due to its having an air valve, which is in the cylinder-head. The gas-and-air mixture is forced into the crank-case through a jet inside the crank-shaft. It comes into the cylinder through half-round openings when the piston is down, the openings being in the guiding flange and small holes machined in the cylinder. When the piston returns it covers the ports and the charge is compressed. A single large valve, in the cylinder-head, is used for exhaust. This valve also stays open for part of the intake stroke to admit air, which is used to dilute the rich mixture of gas.

Gasoline is fed to the engine by air pressure at 5 pounds per square inch, produced by an air pump.

The fuel consumption is about 12 gallons per hour.* Usually a 25-gallon lubricating-oil tank is provided. From the tank a tube leads to the pump inlet. The pump has two outlets to the hollow crank-shaft and a branch from each outlet to a circulation indicator. One of the oil tubes feeds the two rear ball bearings in the thrust-plate housing.

The oil consumption with the Gnome is very high. The centrifugal force of the revolving cylinders tends to throw out the oil through the open exhaust. When the engine has stood for some time a considerable quantity of oil drains to the low cylinders, and when first started this oil is thrown out in quantity, to the sides.

Castor oil is generally used for the lubrication of these engines, due to the fact that this oil is not as quickly washed from the cylinder walls by the incoming rich gasoline mixtures. Castor oil leaves a much more bulky deposit in the explosion chambers than would a mineral oil. The best grade of cold-pressed castor oil should be used. What is known as No. 3 castor oil is not satisfactory, because poor lubrication will result, due to decomposition of this oil, which is more rapid than for the better grade. Some aviators state that No. 3 castor gives out nauseating fumes when used in the engine.

Engines using castor-oil lubricant must be frequently dismounted and cleaned. Some aviators use two-thirds gasoline to one-third oil. The oil supply on most of the engines cannot be controlled.

The oil tends to go straight through the cylinders, due to the centrifugal force. Below, the piston is lubricated by spray from the crank-case.

A sample of first-quality castor oil used for airplane lubrication had the following tests. Tests for comparison are also given, showing results from a sample of No. 3 castor oil, which was tested as an airplane lubricant without good results.

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* NOTE. See later test on Gnome Monosoupape Engine, p. 563.

	First-Grade Castor (Cold Pressed)	No. 3 Castor
Color:	Very pale yellow.	Greenish yellow.
Odor:	Castor.	Strong castor.
Appearance:	Clear bright.	Clear bright.
Baumé:	15.3.	15.7
Sp. grav.:	0.964.	0.961
Flash:	550.	514
Fire:	618.	590
Cold test:	-10° Fahr.	-10° Fahr.
Saybolt Vis.	100° F. 1440	1250
	150° F. 308	275
	200° F. 117	275
	210° F. 96	94
	250° F. 64	64
Acid number:	1.03.	9.64
Free fatty acid:	0.55.	4.90
Iodine value:	88.3.	89.3
Saponification value:	175.8	175.1

As the percentage of free fatty acid increases, so does the tendency to decompose in the presence of heat. This partly explains why No. 3 castor will not give good results.

(See solubility in gasoline tests and other tests on castor oil under heading of "Castor Oil" in index.)

The maker's estimate for the Gnome engine is 7 pints of lubricating oil per hour for a 100 H. P. motor. Its speed at full power is about 1200 R. P. M.

LE RHONE MOTOR.—This is a revolving-cylinder engine, similar in some respects to the Gnome engine. However, it has two valves in the head, one for intake and one for exhaust.

DUESENBERG 16-VALVE ENGINE.—This is a 4-cylinder engine; about 140 H. P. at 2100 R. P. M. Lubrication by oil pump, from base through cored passages to main bearings, thence through tubes to and under each connecting rod to where rod dips and throws the oil. This is also aided by a splash system. Pump pressure about 25 pounds.

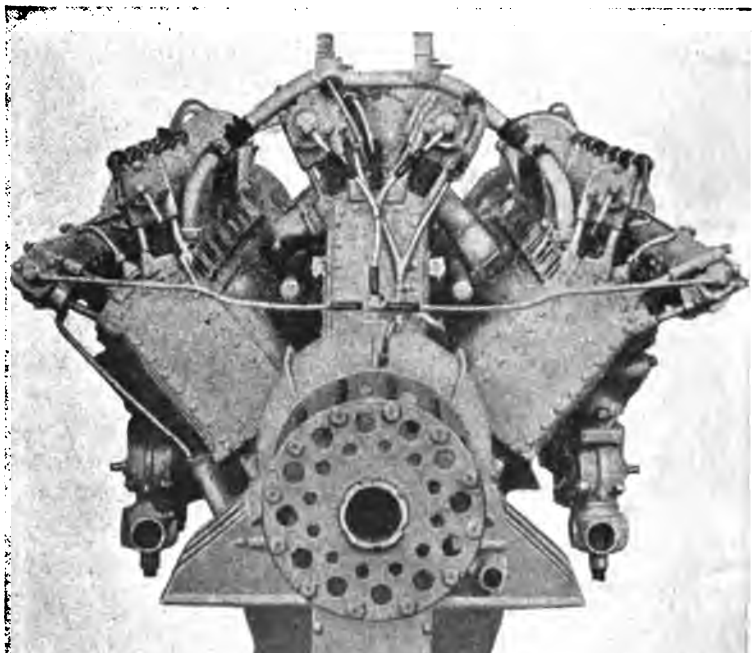

Fig. 2. Sec. 10c.—Sterling Sunbeam 18 cylinder airplane engines. (By permission from Aviation Engines, by Victor W. Page, N. W. Henley Pub. Co.)

HALL-SCOTT.—Four- and six-cylinder engines. High-pressure oiling; oil forced to under side of main bearings. Oil is circulated around a long intake manifold. Large gear pump. Oil passes from pump through a strainer to manifold jacket, to main distributor, to main bearings. Oil pressure at oil gauge will vary according to weather conditions and viscosity of lubricant. For speed of about 1300 R. P. M.; pressure after engine is warmed up is about 8 pounds. Cam-shaft housing lubricated by oil under pressure through direct tube from main distributor to hous-

ing. Cam-shaft gears, etc., lubricated by oil from end of cam-shaft housing overflow.

NOTE. See later section for descriptive data and lubricating notes.

SUNBEAM ENGINES.—Made in various cylinder numbers. The lubricating system is of the dry-base type, with oil pump, filter and cooling system. Has high-pressure gear pump. Fig. 2, Sec. 10c, shows a Sterling Sunbeam, 18-cylinder airplane engine.

BENZ MOTORS.—Water cooled; pair oil pumps, plunger type; also a gear pump. Oil delivered at about 60 pounds, through set of copper pipes in base to main bearings. Fig. 3, Sec. 10c, shows the general arrangement of this type of motor. Fig. 4, Sec. 10c, shows a view of the oil pump.

OTHER ENGINES.—Fig. 5, Sec. 10c, shows a view of the Sturtevant, 210 H. P., model 5A-4 1/2. Fig. 6, Sec. 10c, and Fig. 7, Sec. 10c, show views of the Renault motor, cross section and oiling diagram. Fig. 8 Sec. 10c, shows a view of a Hispano-Suiza motor.

AIRPLANE ENGINES, DATA ON.—The following data of five representative engines are descriptive and interesting, and were taken from a report covering tests of lubricating oils for aeronautical engines, as made by the Aeronautical Division, Signal Corps, U. S. Army:

Name of motor		Curtiss	Curtiss	Curtiss	Hall-Scott	Sturtevant
Type		OXX2	V2C3	V2C10	A7A	5A
No. of cylinders		8	8	8	4	8
Size	Bore	4¼"	5"	5"	5"	5¼"
	Stroke	5"	7"	7"	7"	7"
Rated B. H. P.		100	200	200	100	140
Rated R. P. M.		1400	1400	1400	1400	2000
Carburetor		Zenith	Zenith	Zenith	Zenith	Zenith
Ignition system		Dixie	Berling	Berling	Dixie	Dixie
Starting system		....	Air	Air	....	Air
Oiling system		Pressure	Pressure	Pressure	Pressure	Pressure
Capacity of crank-case		4 gal.	8 gal.	8 gal.	4 gal.	2 gal.
Metals	Cylinder	St. Lining	St. Lining	St. Lining	St. Lining	St. Lining
	Crank-case	Alum.	Alum.	Alum.	Alum.	Alum.
	Piston	Alum.	Alum.	Alum.	Alum.	Alum.
Weight per rated H. P.*		3.80	3.43	3.43	4.32	3.84
Propeller	Type	Blade	Blade	Blade	Club	Club
	Diameter	8'-0"	9'-6"	9'-6"	5'-3 3/16"	5'-11¼"
	Width or pitch	5'-0"	5'-7"	5'-7"	4⅛"	5 5/16"

* NOTE. Weights per H. P. based on a dry motor, without propeller hub. In the case of the Hall-Scott motor, the figure includes hot-air stove, hot-air pipe to carburetor, exhaust pipes and propeller hub, but without front-propeller flange or bolts. Weight of Sturtevant includes the Christenson starter and hub, but not the front plate and bolts.

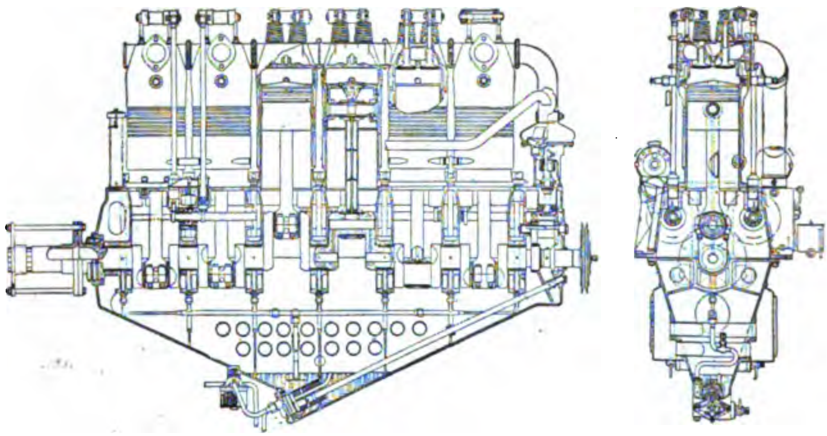

Fig. 3. Sec. 10c.—General arrangement of the 230 H. P. Benz aircraft engine, 145 mm. bore by 190 mm. stroke. (Courtesy *Aviation*.)

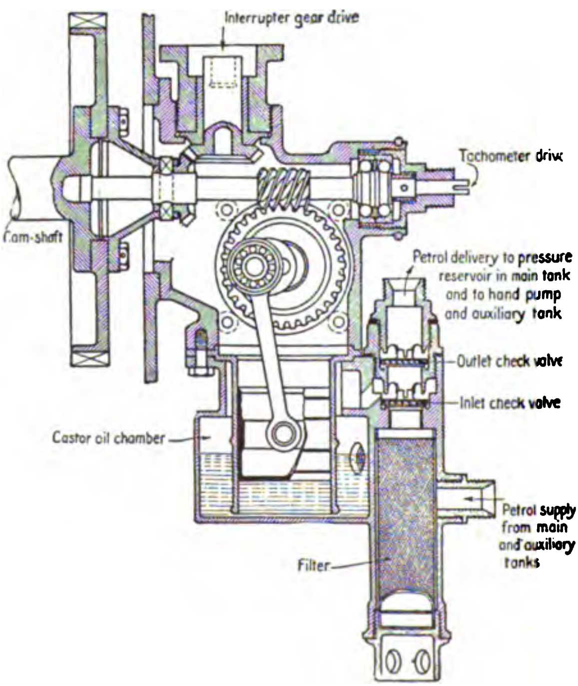

Fig. 4. Sec. 10c.—Oil pump 230 H.P. Benz engine. (Courtesy *Aviation*.)

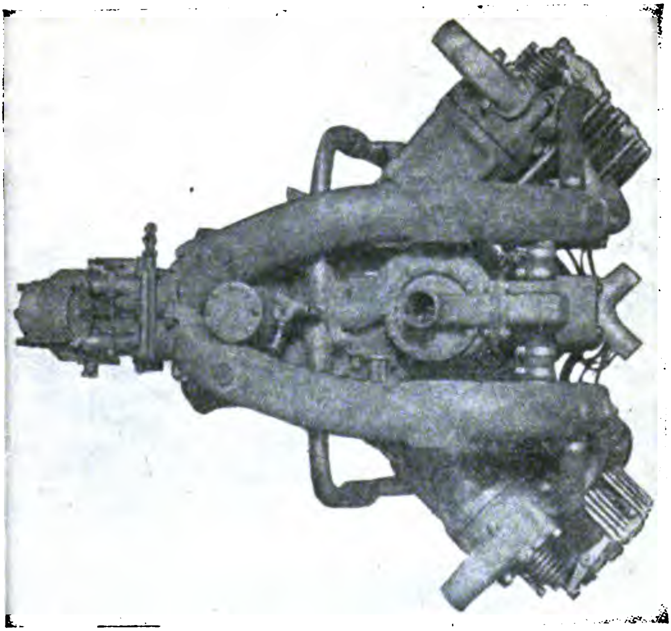

FIG. 5. SEC. 10c.—Sturtevant 210 H.P. motor, model 5a 4½, weight 508 pd. 2.3 pounds per H.P.

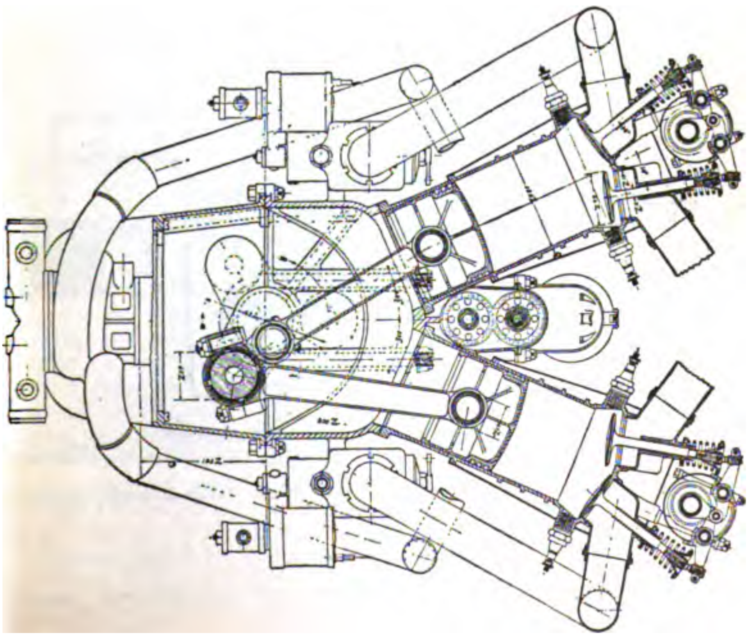

FIG. 6. SEC. 10c.—Cross-section Renault 12 cylinder engine. (Courtesy *Aerial Age*.)

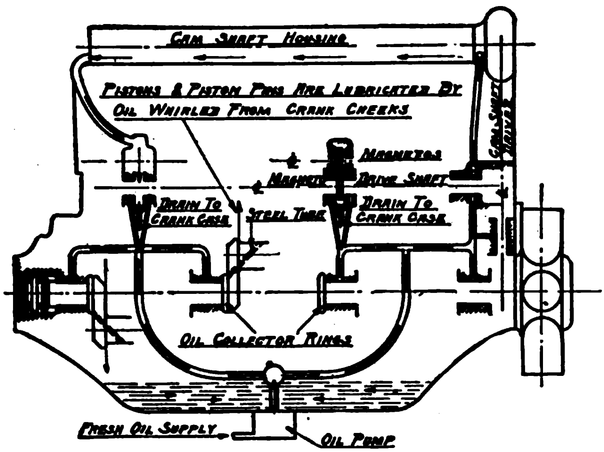

FIG. 7. SEC. 10c.—Oiling diagram, Renault 12 cylinder engine. (Courtesy *Aerial Age*.)

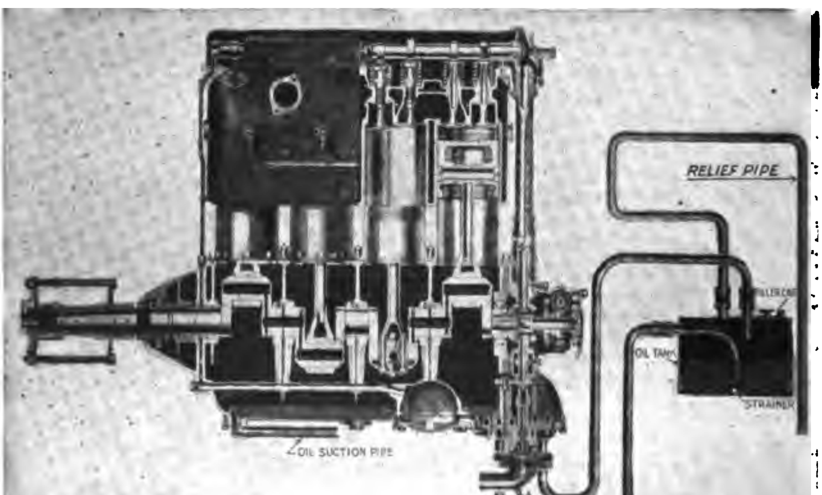

FIG. 8. SEC. 10c.—Hispano-Suiza motor. (Courtesy Wright-Martin Aircraft Corporation.)

LUBRICATION

AIRPLANE ENGINE LUBRICATING SYSTEMS.—Due to continuous operation at full load, the operating temperatures of airplane engines are high. The parts are light. The material for piston rings ranges from brass or bronze to cast iron. Steel against steel, as in the case of steel piston rings and steel cylinder barrels, shows a tendency to overheat locally and cause the oil film to withdraw, which may result in scoring or fusing. Cast iron against steel also shows a tendency to cause overheating locally. Aluminum against steel shows the best results, but requires a greater piston clearance than is required for the other combinations.

* There are two general systems of lubrication, the "wet base," where the entire lubricating oil supply is carried in the pump, and the "dry base," where the entire oil supply is carried in a separate compartment, but connected to the engine by both outlet and inlet connections. The engines are equipped with a full-force feed system. In the case of the dry-base engines, the oil from the bearings drains to the suction side of the pump, located at the bottom of the base. This pump is of greater capacity than is the circulating pump, which supplies the oil to the bearings, thus any accumulation of oil in the crank-case is prevented. The purpose of the dry-base system is to insure positive lubrication when the engine is in any position, as in spiral gliding, nose dives, etc., where even in the case of the dry-base systems there may be an accumulation of several gallons of oil in the crank-case.

The splash system for lubrication is simplest, but is not the best for lubricating airplane engines. The evolutions of the airplane in flight cause the engines to be operated at all angles. This requires that the lubrication be supplied by a system that will deliver an abundant measure of oil, but which will prevent the flooding of the cylinders. With the full-force feed system the oil is distributed under pressure, and after passing through the bearings, drains to the suction end of a pump having a larger capacity than the pressure pump, thus preventing oil accumulating in the crank-case by forcing it into a separate oil reservoir.

Oil gauges are provided on pressure systems to indicate the pressure of oil on the bearings. After five or six hours' running, the oil strainer at the bottom of the crank-case should be removed and cleaned with gasoline. Poor lubrication is usually indicated by pounding and overheating of the engine. The high-compression motors run hotter than the lower compression engines.

The piston rings should be tight. A good plan is to have the lower edge of the piston skirt sharp, with a shallow groove below the lower piston ring. If holes are placed in the piston walls, in the bottom of the shallow ring, the excess oil on the cylinder walls will be scraped off by the sharp-edged piston ring, and then will collect in the shallow groove, passing through the holes described and falling back into the crank-case.

Rocker arms and push rods should be well oiled before every flight.

As previously described, airplane engines are designed to operate at high speeds and full loads for long periods. The operating temperatures are high. The parts are all designed with a view to obtaining the maximum lightness, and the pistons may be made of alloy steel, aluminum or

* NOTE. Vertical and Vee Type engines.

cast iron, and the piston heads are thin. When aluminum pistons are used, the heat is more rapidly carried away, and the lubricating oil is not exposed to as severe conditions. Both water cooling and air cooling are used for airplane engines. Air-cooled engines are usually used for short, fast flights, where lightness is important. Water-cooled engines are used for long flights. Water-cooled engines maintain the temperature of the engine at a more uniform heat, and are not as severe on the lubricant as are the air-cooled engines.

CLEARANCES — INTERNAL - COMBUSTION ENGINES.—(Report, Equipment Division, Signal Corps, U. S. Army.) The following information, which was developed in a report on "Airplane Lubrication," as noted above, and pertaining to clearances and effect on the lubricant, is of interest as an indication of the conditions in general of bearing clearance. The report states as follows: "The clearances that are allowed for bearings lubricated by means of a forced-feed system must be considered in the light of a check or throttle valve to the outlet of the system. Close clearances have the effect of checking the flow of the oil, by reducing the outlet; wide clearances allow of a free passage of the lubricant. Close clearances are always accompanied by high pump pressure, as compared with wide clearances with the same lubricant. Therefore, with the same lubricant, higher pump pressure can be secured by reducing the clearances. With the reduction in clearance, there is a reduction in the amount of oil that flows through a bearing. With the same clearance, it is necessary to decrease the body of the lubricant to increase the flow. In starting an engine with cold oil the pump pressure is high; this pressure falls as the body of the oil is reduced; first, by the heat taken from the pistons in the cylinders; second, from the heat generated by the oil in working through the system and bearings, and third, by the gasoline that has leaked by the rings and is held by the oil.

"The heat of a bearing not affected by outside temperatures is largely due to the fluid friction of the lubricant, the rule being that the heavier the body of the oil the higher the heat due to friction. With the same lubricant on a bearing, an increased flow will reduce the heat by simply carrying it away and not allowing it to accumulate. There is, therefore, an automatic adjustment in the force-feed system with the heavy oil—as the bearing heats the oil feed increases, due to the oil being lighter in body, and this increased feed tends to reduce the temperature of the bearings, and as the temperature is reduced, the body of the oil gets heavier and the flow is checked. It is only necessary to have a large enough supply of oil and a sufficiently large pump to work at any clearance to make overheating almost impossible except in the case of an accident. * * *

"In fitting an oil to a certain clearance, to be at all effective there must be taken into consideration the body of the oil and the temperature. After once securing the proper balance between these three factors, the change of any one will upset the proposition." * * *

CRANK-CASE AIRPLANE ENGINES—OIL TEMPERATURE RANGES.—(Report, Equipment Division, Signal Corps, U. S. Army.) "The temperature range of oil in the crank-case of a Curtiss OXX2 engine on a certain series of tests was from 110° to 140° Fahr; on the Hall-Scott engine, 115° to 165°, and on the Sturtevant engine, 180° to 192° Fahr."

ENGINE PRIMING AND AIRPLANE ENGINE LUBRICATION.—(Report, Equipment Division, Signal Corps, U. S. Army). In connection with the lubrication of airplane engines, the following information was presented in the above-mentioned report: "The present practice in starting airplane engines is to prime freely, especially on cold mornings. * * * Cases are on record where priming was resorted to to such an extent that the gasoline, which had run down to the crank-case, exploded and wrecked the engine. Other cases are on record where, due to priming and washing the lubricant from the walls and the cylinders, damage was done immediately when the engine was started, before the lubricant could get in between the surfaces. There is no question that heating an engine, if only by putting steam through the circulating system, will allow an easy starting and a quick get-away. The reason is that the oil is made more fluid on account of the heating, and, therefore, circulates more freely. It seems wise to establish a complete heating system, if only to overcome the necessity for priming, with a consequent danger and damage to the engine."

AIRPLANE ENGINE LUBRICATION—COLD WEATHER.—In order to eliminate trouble, due to lubrication, in cold weather, an engine heater may be used, which can be attached to each engine in active service, and which consists of a small stove, provided with several gasoline burners, and a copper coil, through which the water from the engine-cooling system circulates and is returned to the top of the radiator. In practice, the heater is connected to the engine as soon as it comes from a flight, in order to keep the engine circulating water and oil warm. Portable oil heaters to warm the oil are also used. Such devices reduce the necessity for priming with gasoline, which tends to wash the lubricating film from the cylinder walls, and may cause considerable trouble, due to poor lubrication. When using a heater, the engine should be run at low speed for a short time, in order to assure free oil circulation and uniform water temperature.

FLASH- AND FIRE-POINT, AIRPLANE ENGINE LUBRICANTS.—In a report presented in connection with airplane lubrication and fuel testing by the Equipment Division, Signal Corps, U. S. Army, the following comments were made with reference to the flash- and fire-points of airplane engine lubricants: "The characteristic of an oil that gives it either a high or low flash- or fire-point is the same as that which gives the same oil a high or low gravity. * * * Consideration has only been given to the finished oils as manufactured, and as they appear in the original packages, or in sample bottles, or upon the records as represented by chemical tests on the new oils; no thought has been given to the flash or fire that the oil would have when in the crank-case or lubricating system of an internal-combustion engine. As a matter of fact, as is clearly demonstrated by record of test, the flash-point of any oil in operation is practically the flash-point of the heavy end of such gasoline as is absorbed by the lubricant, * * * and the power of absorption varies with different oils. The fire-point of a used oil varies from the original to a less extent than the flash-point, because at the high temperature at which the fire-point develops all gasoline and most heavy ends have been driven off."

COLD TEST OR POUR TEST—AIRPLANE ENGINE OIL.—(Report of Equipment Department, Signal Corps, U. S. Army.) "The question of cold test of the oil (airplane engine oil) does not possess value for this work if the oil is handled properly, in accordance with the systems that have been designed for the purpose of heating the engines before they are placed in operation; though low cold test is, as a rule, a valuable adjunct to an oil, as it allows action under low temperature, where oil not possessing this characteristic will be set, and thereby retard the first attempts to start the engine when everything is cold. * * * The cold test of an oil in the engine undergoes a very remarkable transformation, due entirely to the absorption of gasoline or the heavy ends from the gasoline, and in the case of one or two oils tested the change was thought to be probably due to the separation of the basic oils used for making the finished products."

VISCOSITY—AIRPLANE ENGINE OILS.—(Report of Equipment Division, Signal Corps, U. S. Army): "An oil undergoes a very great change in viscosity while it is working in the engine, and this change is due entirely to the leakage of the gas by the piston rings, and, after condensation, to the absorption of the heavy ends by the lubricant. The power of absorption possessed by the lubricant governs the lowering of the viscosity. The oil that will absorb gasoline the least will be reduced in viscosity the least from this cause, and such an oil will more clearly maintain its original body or viscosity while working in the engine than will an oil that has a greater tendency to absorb gasoline. In every case, as indicated by tests, every oil has been reduced in viscosity to a remarkable extent during the first hour of operation. Many of the oils slightly recover during the balance of the test, while others continue to absorb the gasoline and to become further reduced in body. The viscosity, as taken at 212° Fahr., shows but a slight variation, due to gasoline absorption, as at this temperature the oil in the instrument has given up all of the gasoline and practically all of the heavy ends that are responsible for the considerable effect at lower temperatures. The viscosity on the new and used oils at 300° Fahr. is practically identical within the range of era of observation. By consideration of this principle of gasoline absorption, it will be evident that the present method of selecting a lubricant when new, and not considering the viscosity of the oil in the engine, is radically wrong and probably to an extent accounts for many of the engine failures."

CARBON AND SEDIMENT—AIRPLANE ENGINE OILS.—(Report, Equipment Division, Signal Corps, U. S. Army): "Carbon residue determination, as made at the Annapolis Laboratory by the Conradson method, consisted of practically distilling a small portion of the test oil until a residue was left, and then comparing the weight of the residue to the weight of the original sample. The carbon test by the Waters method, as used at the Bureau of Standards, is the difference between the amount of a sample insoluble in petroleum ether before and after oven treatment, this difference being reported as 'carbonization.'

"Volume and Weight Tests: The sediment contained in a sample taken from the circulating system at the end of five hours was precipitated and an indication secured as to the percentage by volume. The sediment was then removed from the oil and weighed in order to secure the per-

centage by weight. This last indication can be taken as a standard in judging the amount of carbonization that takes place in an oil and that is carried with the oil through the circulating system. * * * Charts representing the carbonization value by the Waters method, and showing the percentage of sediment by weight, are very closely related, especially when comparing low specific gravity oils. The carbonization value by the Waters method for the high specific gravity oils is greater than that given for the low specific gravity oils as compared to the sediment by weight; that is, the value by the Waters method seems to be magnified for the high specific gravity oil. The gravity of the oil is very well indicated by the Waters test, there being a wide range between the two general classifications of crude. The Conradson method checks to an extent with the sediment by weight measurements of the low specific gravity oils, but does not check with this reading of the high specific gravity oils. * * * An oil which gave the cleanest engine on the test had the lowest Conradson carbon value for each set of tests, and this oil was reported with a high value by the Waters method. The action of this oil in the engine was that it formed a great amount of carbon which came out of the exhaust in a remarkable manner, but this carbon was not of a nature that allowed it to stick and accumulate inside the engine, and no more of this carbon seemed to go back into the circulating oil than with a number of other oils. The oils that gave the greatest amount of carbon in the engine were those that showed the largest carbon content by the Conradson method and the lowest value by the Waters method, with the exception of the lightest oil tested. This oil in one set of tests showed an excessive consumption, due to its light body, and the carbon in the engine was undoubtedly from that cause.

"With oils of the same classification as to crude, the carbon content, Conradson method, is directly related to the viscosity of the oil at 212° Fahr., and the carbon residue content by the Waters method is directly opposed to the viscosity at 212° Fahr."

DEMULSIBILITY IN AIRPLANE ENGINE OILS.—(Report, Equipment Division, Signal Corps, U. S. Army):

"'Transformer oils, as a rule, have demulsibility of 1200, * * * an additional proof * * * that high demulsibility is an indication of great purity.'

"As 1200 represents an oil of great purity, zero, at the other end of the scale, is taken to represent an unsuitable lubricant. The demulsibility of the oil on one test showed a value of 109. This oil was not at all satisfactory on account of excessive consumption and carbon. Four other oils were reported on with lower numerical value. Thirty-one other tests were reported upon as zero or without any value whatever."

GASOLINE ABSORPTION—INTERNAL-COMBUSTION ENGINE CYLINDER OILS.—(Report, Equipment Division, Signal Corps, U. S. Army.) The referred to report cites the following, regarding the characteristic gasoline absorption possessed by different oils: "During the compression stroke, when the charge of gas is being compressed in the cylinder at a pressure as high as 90 pounds, there is a leakage past the rings, and this gas upon reaching the crank-case is condensed, the heavy ends of the gasoline being absorbed by the lubricant. Should the lubri-

cant be working at constant low temperatures, it would hold a greater proportion of gasoline heavy ends than would be the case with the lubricant working at a temperature that would drive off most of these light products. This is proven by the results of a test where the engine was operated at the highest temperature allowed the same oil to operate at higher flash and higher viscosity after the same length of time than was the case in another engine where the oil was much colder. It is also to be noted that different oils possess the virtue of holding or not holding these heavy ends in different degrees, as can be noted by comparing the drop in flash of a low specific gravity oil, Test A, with the very much less drop in flash of the high specific gravity oil, as indicated in Test B, the readings being as follows:

"Test A: Flash, when new, 440° Fahr.; after five hours, 130° Fahr.

"Test B. Flash, when new, 390° Fahr.; after five hours, 200° Fahr.

"This feature checks through the series of tests and shows that, as a rule, the oils that are of high specific gravity seem to possess the property of not absorbing the heavy ends of the escaped gasoline, though one or two other oils seem to possess this characteristic when working in certain engines. It may be that this characteristic in a heavy lubricating oil is not entirely a matter that is governed by the crude, as would seem to be strongly indicated. It may be a characteristic that has to do with the manufacture of the oil."

"Dr. J. B. Garner, of the Mellon Institute of Industrial Research, has conducted experiments that have not been released for publication, which indicate that the crude from which the oil is made has a great deal to do with the absorbent qualities, and there is no relation between this property and viscosity." According to the report referred to above, Doctor Garner reaches the following conclusions:

"1. The absorbent quality of the asphaltum-base distillates, having the same distillation range, is always less than that of the paraffin-base distillates."

"2. California Mineral Seal is the best asphaltum-base distillate; has an absorbent quality of only 79.1 per cent. of that possessed by Eastern Mineral Seal, the best paraffin-base absorbent. * * *"

"The large number of carefully checked experiments that lead to this conclusion were made by the Mellon Institute for the purpose of finding the oil that would absorb gasoline to the greatest extent. From a close consideration of all the facts and tests resulting from the present work, the oil for the lubrication of an airplane engine should be an oil that will absorb gasoline to the least extent, as such an oil will undergo the slightest change in the engine."

TESTS ON LUBRICANTS AND FUELS FOR AIRPLANE OPERATION.—(From report of tests conducted by Signal Corps, Aeronautical Division, U. S. Army): The following tables of tests data, which were taken from report of tests conducted by the Aeronautical Branch of the Signal Corps, are very interesting, as they cover a wide range of oils from different crudes and are complete, both from the standpoint of original tests of the oils and tests of the lubricants after use, as well as consumptions and power developed. These tests were carried on with 5 engines—3 Curtiss, 1 Hall-Scott and 1 Sturtevant. (See previous section for data regarding engines.) See tables following:

Motor = Curtiss Type = V2C10 H. P. rated = 200 Carburetor = 2-Zenith Ignition = Berling.—(*Continued*)

Test No.	32		35		36		25		28		21		17	
	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finis
Specific gravity	.8931	.8942	.8972	.8968	.8899	.8880	.9250	.9235	.9136	.9136	.9478	.9465	.9450	.944
Baumé gravity	26.73	26.55	25.98	26.05	27.28	27.62	21.33	21.60	23.21	23.24	17.68	17.90	18.17	18.3
Flash-point (° F)	460	212	425	190	440	200	396	198	398	222	388	222	342	220
Fire-point (° F)	585	585	520	508	540	538	478	478	502	494	482	458	480	455
Pour test (° F)	50	44	42	25	55	28	9	25	30	5	20	9	0	Belo −5
Viscosity Sayb. at 100° F.	1744	1416	842	743	1258	1007	1447	1108	1475	1254	1223	1003	1695	1432
Viscosity at 130° F.	696	587	356	325	525	426	497	408	552	478	398	351	515	505
Viscosity at 212° F.	129	118	88	85	108	105	96	84	102	100	72	70	80	80
Viscosity at 300° F.	56	56	46	45	52	51	51	45	48	49	41	40	42	42
Conradson carbon, per cent.	1.63	2.06	1.08	1.56	.88	1.33	1.45	1.84	0.97	1.44	.35	.80	.53	1.00
Conradson carbon, nature	Hard slightly adhesive	Hard adhesive	Hard adhesive		Hard adhesive		Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Crusty adhesive	Hard granular adhesive	Loose flaky	Har adhesi
Carbon (Waters)	Trace	.08	Trace	.34	Trace	.07	.52	1.21	0.08	.20	1.18	1.49	.22	1.46
Acid number	.10	.12	.07	.16	.07	.10	.06	.10	.07	.11	.63	.77	.05	.14
H_2O per cent.	0	0	0	Trace	0	0	.86	0	Trace	0	Trace	0	0	0
Color	Deep green red	Black	Red	Black	Red	Black	Dark red brown	Black	Dark red	Black	Dark red	Black	Red	Blac
Demulsibility	....	0	....	0	....	0	....	....	8	0	0	0	....	0
Residue volume per cent.	....	24	....	25	....	14	....	22	....	28	....	22	....	20
Residue weight per cent.	....	.25	....	.47	....	.27	....	.59	....	.51	....	.41	....	.37
Ash	....	.020	....	.030	....	.013	....	.097	....	.095	....	.34	....	.048
Fe_2O_3														
Gasoline, per cent. evaporated	....	1.36	....	1.99	....	1.90	....	1.55	....	1.52	....	.89	....	1.62
Gasoline, per cent. distributed	....	1.75	....	1.95	....	2.2	....	0.5	....	1.2	....	1.5	....	0.25
Barometer	30.06		30.16		30.29		30.30		30.05		29.77		29.75	
Humidity	.004551		.004607		.003184		.003805		.003940		.004203		.005526	
Weather condition	Cloudy		Cloudy		Cloudy		Cloudy		Cloudy		Clear		Cloudy	
Temperature dry bulb	41.7		40.2		35.6		37.0		50.0		48.1		51.6	
Duration of run	5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.	
Average R. P. M.	1334.7		1303.6		1319.6		1312.8		1349.4		1353.0		1332.1	
Average H. P. developed	181.5		170.5		178.9		175.8		184.4		185.1		175.3	
Gasoline, lb. per hr.	123.0		118.4		121.14		121.8		123.6		120.6		116.4	
Gasoline, lb. B.H.P./hr.	.6778		.6951		.6771		.6929		.6702		.6516		.6638	
Lubricating oil, lb. per hr.	4.63		7.036		5.74		7.08		6.52		12.02		9.73	
Lubricating oil, gal. per hr.	.621		.940		.773		.918		.856		1.521		1.235	
Lubricating oil, lb. B. H. P./hr.	.02551		.04131		.03208		.04028		.03536		.06494		.05549	
Lubricating oil, gal. B. H. P./hr.	.00342		.00552		.00432		.00522		.00464		.00821		.00705	
Temp. of oil, end of run ° Fahr.	55.3		53.3		....		....		59.0		....		....	
Remark reference	A C		A C		A B		A B		A C		A B		A B	

Note A.—Average figures based on readings for entire run.
Note B.—Absence of oil temperature due to rise of radometer which did not register to low enough point.
Note C.—Low temperature due to cooling effect of blade propeller.

Test No.	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
Specific gravity	.8914	.8921	.8976	.8990	.8901	.8912	.8932	.8942	.8925	.9247	.8907	.8911	.9478	.9495
Baumé gravity	27.06	26.93	25.90	25.70	27.25	27.01	27.43	27.84	21.35	21.40	26.13	27.09	17.70	17.45
Flash-point (° F.)	455	240	410	218	435	230	440	220	394	222	440	225	394	210
Fire-point (° F.)	600	526	520	516	535	532	552	538	484	464	540	540	472	442
Pour test (° F.)	56	34	42	28	57	40	45	37	8	Below zero	52	25	20	9
Viscosity Sayb. at 100° F.	1745	1650	842	786	1260	1213	1254	1142	1442	1252	1340	1216	1224	1090
Viscosity at 130° F.	700	663	358	340	524	510	525	477	496	445	549	510	399	374
Viscosity at 212° F.	133	135	87	85	117	110	107	104	91	90	109	108	73	74
Viscosity at 300° F.	55	59	48	47	53	52	52	51	45	41	51	51	41	43
Conradson carbon, per cent.	1.65	2.09	1.03	1.55	.77	1.30	.91	1.27	1.49	2.01	1.00	1.46	.83	1.12
Conradson carbon, nature	Loose flaky	Hard adhesive	Hard adhesive		Loose flaky	Hard adhesive	Hard adhesive	Hard adhesive	Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Crusty adhesive	Hard adhesive
Carbon (Waters)	Trace	0.09	Trace	.28	Trace	0.09	Trace	0.10	.55	.96	Trace	.23	1.03	1.56
Acid number	.14	.14	.09	.12	.07	.18	.07	.14	.06	.12	.06	.14	.67	.64
H_2O per cent.	0	0	0	0	0	Trace	0	0	.60	0	0	0	0	0
Color	Red deep green	Black	Red	Black	Red	Black	Red	Black	Dark red brown	Black	Red	Black	Dark red	Black
Demulsibility	0	0	....	0	....	0	43	....	....	0	0	0	....	0
Residue volume per cent.	....	12.0	....	24	....	28	....	13	....	20	....	22	....	27
Residue weight per cent.	....	.37	....	.49	....	.43	....	.32	....	.88	....	.35	....	.72
Ash	....	.06	....	.008	....	.065	....	.024	....	.07	....	.035	....	.32
Fe_2O_3														
Gasoline, per cent. evaporated	....	.40	....	1.08	....	.91	....	.97	....	1.00	....	1.12	....	.71
Gasoline, per cent. distributed	....	0.5	....	0.53	....	1.0	....	.5	....	1.5	....	1.5	....	1.5
Barometer	30.41		30.07		30.30		29.57		30.27		30.16		30.03	
Humidity	.004524		.005203		.004958		.005572		.005307		.004845		.003683	
Weather condition	Cloudy		Slightly overcast		....		Snow and rain		Rain					
Temperature dry bulb	55.3		40.6		58.6		42.1		40.7		47.6		37.2	
Duration of run	5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.	
Average R. P. M.	1327.4		1337.7		1338.6		1341.3		1340.7		1339.3		1339.8	
Average H. P. developed	89.1		93.7		92.4		91.4		94.1		92.2		94.4	
Gasoline, lb. per hr.	40.40		52.89		67.60		52.67		53.82		54.58		56.22	
Gasoline, lb. B.H.P./hr.	.5544		.5643		.7311		.5764		.5718		.5919		.5958	
Lubricating oil, lb. per hr.	3.27		4.78		3.36		2.97		4.32		4.25		5.22	
Lubricating oil, gal. per hr.	.439		.638		.453		.040		.560		.572		.661	
Lubricating oil, lb. B. H. P./hr	.03624		.05054		.03605		.03214		.04546		.04564		.05501	
Lubricating oil, gal. B. H. P./hr	.00487		.00675		.00472		.00453		.00589		.00615		.00696	
Temp. of oil, end of run	115		133		166		163		142		163		156	
Remark reference	A		A		A		A		A		A		A	

Note A.—Excepting Tests 23 and 34, first one-half hour run was under condition of wide open throttle. Figures based on readings of barometer, thermometers, R. P. M., gasoline and oil consumption, are averages of 4½ hour run at approximately 90% full load.

	Motor = Hall-Scott Type = A7A H. P. rated = 100 Carburetor = Zenith Ignition = Dixie						Motor = Sturtevant Type = 5A H.P. rated = 140 Carburetor = Zenith Ignition = 2 Dixie Magnetos			
Test No.	16		23		34		4		9	
	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
Specific gravity	.9442	.9454	.9150	.9162	.8890	.8902	.8897	.8870	.8967	.8952
Baumé gravity	18.26	18.07	23.00	22.79	26.67	26.51	27.30	27.79	26.06	26.33
Flash-point (° F.)	360	228	440	206	300	225	450	220	425	200
Fire-point (° F.)	472	472	524	483	619	616	605	580	530	516
Pour test (° F.)	0	Below −5	40	7	50	40	48	40	42	35
Viscosity Sayb. at 100° F.	1681	1482	1003	1004	2370	2125	1780	1593	906	815
Viscosity at 130° F.	816	487	410	378	910	831	706	650	381	351
Viscosity at 212° F.	81	86	86	85	159	158	138	128	91	85
Viscosity at 300° F.	42	43	44	44	59	62	57	58	46	46
Conradson carbon, per cent.	.54	1.40	1.77	2.50	1.89	2.20	1.36	1.58	.99	1.17
Conradson carbon, nature	Loose flaky	Hard granular adhesive	Hard adhesive	Hard adhesive	Hard adhesive		Loose flaky	Hard flaky	Hard adhesive	
Carbon (Waters)	.22	1.02	.57	1.19	Trace	.10	Trace	.05	Trace	.07
Acid number	.07	.14	.07	.10	.07	.14	.10	.14	.07	.14
H_2O per cent.	0	0	0	0	0	0	0	0	0	0
Color	Red	Black	Red green black	Black	Dark green	Black	Dark green	Black green tinge	Red	Black
Demulsibility	....	0	....	....	....	0	12	0	30	0
Residue volume per cent.	....	36	....	30	....	32	....	Too dark to read	....	5.6
Residue weight per cent.	....	.71	....	.82	....	.36	....	.07	....	.07
Ash	....	.016	....	.832	....	.025	....	.03	....	.006
Fe_2O_3										
Gasoline, per cent. evaporated	....	1.20	....	1.58	....	.88	....	.60	....	.95
Gasoline, per cent. distributed	....	0.25	....	1.7	....	1.2	....	1.5	....	1.0
Barometer	29.35		30.79		30.13		30.37		30.39	
Humidity	.007473		.003503		.004014		.003039		.004496	
Weather condition			....		Clear		Clear		Cloudy	
Temperature dry bulb	53.0		34.1		43.5		70.8		57.6	
Duration of run	5 hrs.		5 hrs.		5 hrs.		5 hrs.		3 hrs. 10 min.	
Average R. P. M.	1341.7		1339.8		1341.4		1912.1		1926.5	
Average H. P. developed	89.8		98.3		93.4		125.9		115.7	
Gasoline, lb. per hr.	55.96		59.86		56.45		87.26		89.0	
Gasoline, lb. B.H.P./hr.	.6230		.6090		.6042		.6931		.6603	
Lubricating oil, lb. per hr.	4.65		4.39		3.45		10.85		11.64	
Lubricating oil, gal. per hr.	.591		.575		.463		1.461		1.557	
Lubricating oil, lb. B. H. P./hr.	.05129		.04466		.03693		.08618		.1003	
Lubricating oil, gal. B. H. P./hr.	.00652		.00585		.00425		.01161		.01344	
Temp. of oil, end of run	149		150		167		192		180	
Remark reference			B		B		A		A B	

Note A.—Excepting Tests 23 and 34, first one-half hour run was under condition of wide open throttle. Figures based on readings of barometer, thermometers, R. P. M., gasoline and oil consumption, are averages of 4 hour run at approximately 90% full load.

Note B.—On Tests No. 23 and 34, engine did not reach rated output with wide open throttle. Figures are average of entire run.

Note C.—Average based on readings for entire run.

Note D.—Damage to rocker arm support stud on No. 8. Cylinder and key on Reduction Gear Shaft caused shut down after 3 hours 10 minutes.

Test No.	2 Start	2 Finish	16 Start	16 Finish	5 Start	5 Finish	7 Start	7 Finish	10 Start	10 Finish	13 Start	13 Finish	20 Start	20 Finish
ecific gravity	.8900	.8890	.8962	.8956	.9118	.9088	.8965	.8970	.8904	.8896	.8897	.8876	.8933	.8889
umé gravity	27.30	27.48	25.82	26.27	23.51	24.02	26.07	26.05	27.21	27.32	27.32	27.77	26.69	27.48
ash-point (° F.)	484	140	265	125	376	165	430	135	440	150	440	100	466	160
re-point (° F.)	623	620	528	505	465	445	525	520	545	525	540	530	598	592
our test (° F.)	55	40	38	21	42	29	40	26	54	43	50	37	53	44
y. viscosity at 100° F.	1774	1408	936	688	340	297	900	730	1258	940	1333	875	1780	1090
y. viscosity at 130° F.	710	544	432	312	157	143	381	331	526	410	544	390	683	479
y. viscosity at 212° F.	135	126	91	84	54	54	87	83	107	97	110	100	126	120
y. viscosity at 300° F.	57	56	47	47	39	38	46	46	51	50	51	50	54	53
onradson carbon, per cent	1.17	1.85	1.34	1.57	.31	.58	.86	1.49	.80	1.15	.97	1.16	1.65	1.78
onradson carbon, nature	Loose flaky	Hard flaky	Hard slightly adhesive	Hard adhesive	Loose flaky	Hard flaky	Hard adhesive		Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Flaky adhesive	Hard adhesive
arbon (Waters)	Trace	.08	.16	.29	.47	.99	.01	.31	Trace	.04	.01	.12	Trace	.06
cid number	.21	.38	.05	.11	.14	.24	.07	.21	.10	.21	.04	.21	.03	.10
O per cent	0	0	0	0	0	0	0	0	0	0	0	Trace	0	Trace
olor	Dark green	Black green tinge	Deep red	Black	Red	Black	Red	Black	Red	Black	Red	Black	Deep green red	Black
emulsibility	0	0	....	0	109	0	45	0	....	0	....	0	....	0
esidue, volume	....	Too dark to read	....	12.0	....	14.0	....	Too dark to read	....	14.0	....	Too dark to read	....	Too dark to read
esidue, weight	....	.25	....	.37	....	.25	....	.57		.23		.10		.064
sh	....	.02	....	.035	....	.17	....	.027	....	.007	....	.065	....	Trace
e_2O_3														
asoline, per cent. evaporated	....	2.32	....	3.48	....	1.88	....	2.16	....	2.50	....	3.15	....	2.88
asoline, per cent. distributed	....	2.0	....	1.0	....	2.0	....	2.5	....	2.0	....	3.0	....	0.5
arometer	30.39		29.86		30.19		30.47		30.13		30.40		29.77	
umidity	.003656		.005715		.005061		.004183		.004807		.003788		.004948	
eather condition	Clear		....		Clear		Cloudy		Clear		....		....	
emperature dry bulb	58.0		46.0		67.2		42.4		63.0		44.5		44.6	
uration of run	5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.	
verage R. P. M.	1447.4		1452.5		1451.2		1452.8		1453.9		1443.7		1323.9	
verage H. P. developed	91.6		92.1		89.2		94.3		90.1		91.8		69.3	
asoline consumption, lb. per hr.	67.02		66.16		62.8		63.2		69.8		63.56		59.44	
asoline consumption, lb. B. H. P./hr.	.7316		.7183		.7041		.6702		.7740		.6924		.8572	
ubricating Oil consumption, lb. per hr.	1.43		2.24		6.73		1.75		2.26		2.63		1.59	
ubricating Oil consumption, gal. per hr.	.194		.229		.885		.234		.304		.354		.213	
ubricating Oil consumption, lb. B. H. P./hr.	.01549		.02432		.07436		.01843		.02489		.02845		.02293	
ubricating Oil consumption, gal. B. H. P./hr.	.00217		.00324		.00978		.00246		.00335		.00383		.00316	
emp. of oil, end of run	110° F.		127° F.		125° F.		105° F.		140° F.		122° F.		86° F.	
emark reference	A		B		B		A		A		A		B	

Note A.—Excepting Tests No. 5, 16 and 20, first one-half hour of run was made under condition of wide open throttle. Figures based on readings of barometer, thermometers, R. P. M., gasoline and oil consumption are averages of 4½ hours run at approximately 90% full load.

Note B.—On Tests No. 5, 16 and 20, engine did not reach rated output with wide open throttle. Figures are averages of entire run.

Motor = Curtiss Type = V2C3 H.P. rated = 200 Carburetor = 2 Zenith.

Test No.	6		33		11		27		30		15		19	
	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
cific gravity	.8897	.8917	.8923	.8989	.8897	.8892	.9244	.9224	.9136	.9146	.8892	.8867	.9485	.9413
umé gravity	27.30	26.95	26.88	25.80	27.34	27.39	21.43	21.80	23.21	23.07	27.41	27.86	17.60	18.74
sh-point (° F.)	410	150	425	165	440	140	388	158	414	178	440	130	390	200
e-point (° F.)	606	580	518	510	545	530	485	468	498	492	540	530	480	468
ur test (° F.)	54	29	42	23	56	29	9	20	30	5	47	34	20	6
. viscosity at 100° F.	1755	1232	843	692	1272	874	1448	787	1474	1055	1336	809	1224	761
. viscosity at 130° F.	729	527	357	312	526	397	496	315	549	430	550	374	398	288
. viscosity at 212° F.	135	117	82	80	114	97	90	82	103	94	109	98	73	69
. viscosity at 300° F.	57	57	48	47	52	47	45	47	49	50	51	50	42	42
nradson carbon, per cent	1.35	1.97	.98	1.52	.81	1.41	1.46	2.13	.99	1.85	.95	1.38	.37	1.00
nradson carbon, nature	Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Loose flaky		Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Loose flaky	Hard adhesive	Crusty slightly adhesive	Hard granular
rbon (Waters)	Trace	.13	Trace	.38	Trace	.13	.56	1.94	.08	.31	.01	.20	1.07	1.55
id number	.10	.14	.10	.14	.07	.21	.09	.12	.05	.12	.07	.17	.67	.81
O per cent	0	Trace	0	Trace	0	Trace	.70	Trace	0	Trace	0	Trace	0	0
lor	Dark green red	Black	Red	Black	Red	Black	Dark red brown	Black	Dark red	Black	Red	Black	Dark red	Black
mulsibility	0	0	....	0	....	0	....	0	12	0	0	0	....	0
sidue, volume	....	Too dark to read	....	30	....	24	....	Too dark to read	....	44	....	28	....	17
sidue, weight	....	.57	....	.62	....	.48	....	.95	....	.85	....	.34	....	.59
1	....	.17	....	.025	....	.053	....	.09	....	.093	....	0.54	....	.34
O₂														
soline, per cent. evaporated	....	2.28	....	2.80	....	3.65	....	3.25	....	2.79	....	3.75	....	2.60
soline, per cent. distributed	....	2.5	....	0.32	....	2.5	....	1.75	....	0.51	....	1.5	....	2.5
rometer	30.19		30.15		30.16		30.17		30.03		30.00		25.52	
midity	.006833		.003778		.004232		.005524		.004334		.004619		.006901	
ather condition	Clear		Clear		Clear		Rain		Cloudy		Clear		Cloudy	
mperature dry bulb	62.3		39.8		52.5		41.5		41.9		51.2		56.4	
ration of run	5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		5 hrs.		4 hrs.	
erage R. P. M.	1305.4		1326.3		1319.2		1294.7		1334.0		1338.1		1335.4	
erage H. P. developed	163.3		179.3		172.1		166.6		180.7		179.1		174.4	
soline nsumption: lb. per hr.	136.9		114.0		120.8		137.16		119.6		142.3		117.25	
soline nsumption: lb. B. H. P./hr.	.8383		.6357		.7020		.8234		.6618		.7944		6611	
bricating Oil nsumption: lb. per hr.	4.16		7.64		6.21		7.012		6.694		5.30		8.70	
bricating Oil nsumption: gal. per hr.	.51		1.026		.837		.909		.879		.714		1.109	
bricating Oil nsumption: lb. B. H. P./hr.	.02547		.04260		.03609		.04210		.03704		.02959		.04944	
bricating Oil nsumption: gal. B. H. P./hr.	.00343		.00572		.00486		.00546		.00487		.00399		.00625	
mp. of oil, end of run	....		59° F.		....		....		59° F.		....		72° F.	
mark reference	A B		A C		A B		A B		A C		A B		A C D	

Note A.—Averages based on entire run. Note B.—Absence of oil temperature due to use of radometer, which did not register to low enough point.
Note C.—Low temperature due to cooling effect of blade propeller. Note D.—Shut down after 4 hours due to excessive sparking at exhaust.

GRAPHITE MIXTURES, AIRPLANE LUBRICATION.—The following tests were described and made by the Aeronautical Section, Signal Corps, U. S. Army, on a Hall-Scott motor. The oils tested represent graphite mixtures and high-grade pale filtered stocks of both paraffin and asphaltic series. Comment is called in the report to Test B-1, during which a medium heavy lubricant of a suspended graphite-in-oil mixture was used, as follows: "This oil was consumed in such quantities that the liberal estimate allowed proved entirely too little, and it was necessary to close the run at the end of four hours on account of it. Also, due to the fact that oil was added so continuously and in such excessive quantities, there was found but little difference between the unused oil and the samples periodically removed from the crank-case. The carbon formation on this run was very unusual and entirely different from any of the deposits noted on any of the previous runs. In nature it was hard and crystalline—almost diamond-like. It showed a strong affinity for the metal, not as an adhesive property, but rather as if brazed into the metal, so as to form a sort of case-hardened surface. The deposit was removed only with the greatest difficulty, it being necessary in some cases to take a little of the metal with the carbon in order to get it free."

The complete analyses of the three lubricants used in Tests B-1, B-2 and B-3 are given as follows; also the general data: (See page 556. Test B-1 refers to the graphite mixture, B-2 to the paraffin series oil and Test B-3 to an asphalt series oil.)

COMPARATIVE TESTS OF GRAPHITED-OIL MIXTURE, AND PARAFFIN- AND ASPHALT-BASE OILS

Hall-Scott Motor

Rated 100 H. P. Carbureter = Zenith

Test No.	B 1		B 2		B 3	
	Start	Finish	Start	Finish	Start	Finish
Specific gravity	.9006	.8998	.8727	.8728	.9306	.9288
Baumé gravity	25.42	25.56	30.45	30.43	20.45	20.72
Flash-point (° F.)	370	208	395	197	370	186
Fire-point (° F.)	454	434	520	516	450	422
Pour test (° F.)	37	30	42	28	0	Below 0
Viscosity Say. at 100° F.	190	188	577	530	733	591
Viscosity Say. at 130° F.	106	102	269	254	277	230
Viscosity Say. at 212° F.	45	46	73	72	59	58
Viscosity Say. at 300° F.	37	38	48	47	40	40
Carbon Conradson, per cent.	0.38	0.67	0.15	0.38	0.06	0.38
Carbon Conradson, nature	Loose flaky	Hard adhesive	Hard adhesive	Hard granular	Hard adhesive	Hard adhesive
Carbon, waters	1.26	1.49				
Acid number	0.12	0.17	0.10	0.14	.09	.15
H_2O, per cent.	0	Trace	0	0	0	0
Color	Black	Black	Almost colorless	Black	Red	Black
Demulsibility	0	0				
Residue, volume, per cent.	....	Too dark to read	....	Too dark to read	....	31
Residue, weight, per cent.	....	.59	....	.32	....	.56
Ash	....	0.05	....	0.01	....	0.01
Fe_2O_3	....	....	....	....	....	....
Gasoline, % by evaporation	....	1.20	....	1.47	....	1.78
Gasoline, % by distillation	....	1.0	....	1.0	....	1.5
Barometer	30.43		30.33		30.58	
Humidity	0.004099		0.004034		0.003266	
Weather condition	Partly cloudy		Cloudy		Snowing	
Temperature, dry bulb	42.8		49.0		32.0	
Duration of run	4 hours		5 hours		5 hours	
Average, R. P. M.	1338.5		1349.4		1341.4	
Average H. P. developed	93.5		96.6		100.1	
Gasoline, lb. per hr.	55.91		53.96		55.0	
Gasoline, lb., B. H. P. hr.	0.5978		0.5587		0.54937	
Lubricating oil, lb. per hr.	10.925		5.38		5.95	
Lubricating oil, gal. per hr.	1.455		0.739		0.704	
Lubricating oil, lb. B. H. P. hr.	0.11609		0.05525		0.05929	
Lubricating oil, gal. B. H. P. hr.	0.0154		0.00763		0.00701	
Temp. oil, end of run	156.2		....		136.4	

NOTE.—Figures based as readings of barometer, thermometer, R. P. M., gasoline and oil consumption are averages of 4½ hours run at approximately 90% full load.

TESTS OF LUBRICANTS—GNOME MONOSOUPAPE ENGINE. —In a series of tests conducted by the Aeronautical Section, Signal Corps, U. S. Army, on a Gnome Monosoupape 9-cylinder engine, the following information regarding lubricating requirements of engines of this type using straight castor and castor and mineral oils mixed in various proportions was secured: The engine tested was a Gnome Monosoupape, or single-valve engine, 9-cylinder unit, 100 H. P., capacity rated at 1200 R. P. M. The following data are descriptive of the unit:

Type: B-2. Manufácturer: General Vehicle Co.

Number of cylinders: 9.

Size:

Bore: 110 mm.

Stroke: 150 mm.

Piston rings: 1 obturator; 1 piston ring.
Rated H. P.: 100.
Rated R. P. M.: 1200.
Ignition: Berling magneto; fixed spark at 18°.
Oiling system: Pressure.
Weight per rated H. P.: 2.7 pounds.

"There is no carburetor for the handling of the fuel. Gasoline is fed under pressure to the open crank-case and sprayed through a jet, forming an over-rich mixture in the case. This mixture is drawn into the cylinders through ports, which are uncovered at the proper point in the stroke, and is there mixed to the desired proportions with air drawn through the exhaust valve. The lubricating oil is forced under pressure through tubing and hollow parts, so as to feed all the bearings and pins in the crank-case, and that oil which escapes from the numerous ends is carried outward by a centrifugal force to feed the piston surfaces. The crank-shaft on this type of engine is stationary and the cylinder revolves around it. Naturally the cooling of the cylinder must be effected by the air, and with the low efficiency of heat conduction for air there are involved higher temperatures of the cylinders than is the case with most water-cooled types of engines. This fact, together with the more important one of mixing the rich gasoline vapor and the lubricating oil in the crank-case, has led to the specification of vegetable castor oil for the lubrication of engines of this design. * * *"

"In this series of tests several different compoundings were tried, varying from straight castor oil down to a compound with a 10 per cent. mineral base. When compounded, the mineral oil was a high-grade product of heavy pale filtered stock from asphaltic crude. Since the castor will not mix without separation in time, care was taken in each instance prior to the test to see that just before the start of the run the two constituents were thoroughly agitated until a close mixture was secured." The oils tried are listed as follows:

C–1	19.84% mineral oil and	80.16% castor oil.
C–2	58.98% mineral oil and	41.02% castor oil.
C–3	78.76% mineral oil and	21.24% castor oil.
C–4	88.99% mineral oil and	11.01% castor oil.
C–5		100.00% castor oil.

The complete tests of the oils are as follows:

TEST SUMMARY OF RESULTS WITH CASTOR OIL AND MINERAL AND CASTOR OIL COMPOUNDS WITH GNOME ENGINE

(From report of Acronautical Section, Signal Corps, U. S. Army)

Test No.	C-1		C-2		C-3		C-4		C-5	
	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
Specific gravity	94.40	....	.9395	....	.9220	....	.9321	....	.9615	....
Baumé gravity	18.30	....	19.02	....	21.35	....	20.38	....	15.59	....
Flash-point, ° Fahr.	270	....	366	....	380	....	370	....	485	....
Fire-point, ° Fahr.	432	....	452	....	452	....	454	....	605	....
Pour test, °Fahr.	0	....	0	....	1	....	3	....	0	....
Viscosity at 100° F.	890	....	864	....	510	....	618	....	1405	....
Saybolt at 130° F.	366	....	342	....	208	....	261	....	542	....
Universal at 212° F.	83	....	67	....	57	....	58	....	103	....
Viscosimeter at 300° F.	49	....	43	....	40	....	41	....	53	....
Carbon, per cent.	0.29	....	0.20	....	0.15	....	0.12	....	0.34	....
Conradson, nature	Hard adhesive	....	Hard adhesive	....	Hard adhesive	....	Flaky slightly adhesive	....	Loose flaky	....
Carbon (waters)	....	....	....	....	....	....	....	....	....	....
Acid number	2.73	....	4.76	....	0.49	....	0.35	....	2.03	....
H_2O per cent.	0	....	0	....	0	....	0	....	0	....
Color	Pale yellow	....	Cloudy yellow	....	Pale yellow	....	Pale yellow	....	Very pale yellow	....
Demulsibility	....	....	....	....	....	....	....	....	....	....
Residue { Volume	....	....	....	....	....	....	....	....	....	....
Residue { Weight	....	....	....	....	....	....	....	....	....	....
Per cent. castor oil	80.16	....	41.02	....	21.24	....	11.01	....	100	....
Per cent. mineral oil	19.84	....	58.98	....	78.76	....	88.99	....	0	....
Gasoline { Per cent. by evaporation	....	....	....	....	....	....	....	....	....	....
Gasoline { Per cent. by distillation	....	....	....	....	....	....	....	....	....	....
Barometer	29.67		29.89		29.95		30.19		30.04	
Humidity	.004040		.002907		.003275		.003466		.004210	
Weather condition	Cloudy		Cloudy		Cloudy		Cloudy		Clear	
Temperature (dry bulb)	36		34		33		31		37	
Duration of run	2 hours		2 hours		2 hours		2 hours		2 hours	
Average R. P. M.	1214.6		1190.4		1197.0		1198.1		1185.5	
Average H. P. developed	113.9		108.6		110.7		111.9		106.7	
Gasoline consumption { Pounds per hr.	93.35		86.65		89.25		93.8		84.75	
Gasoline consumption { Pounds B. H. P./hr.	.8196		.7980		.8065		.8383		.7940	
Lubricating oil consumption { Pounds per hour	21.3		19.73		19.55		21.75		20.6	
Lubricating oil consumption { Gallons per hour	2.70		2.50		2.54		2.80		2.57	
Lubricating oil consumption { Pounds B. H. P. per hour	.1870		.1817		.1767		.1944		.1930	
Lubricating oil consumption { Gallons B. H. P. per hour	.0238		.0231		.0230		.0251		.0240	

"In making the tests, a record was made of the reading of the revolutions counter and the level in the gasoline and oil tanks. * * * Each run was of two hours' duration, and throughout the period readings were made as follows:

10-Minute Intervals	30-Minute Intervals	As necessary or at end of run
Barometer.	Wet-bulb thermometer.	Gasoline consumption.
Temperature of run.	Dry-bulb thermometer.	Oil consumption.
R. P. M.		

"* * * The consumption of gasoline and lubricating oil was ascertained by weighing. * * * Since there was no oil in the crank-case at the end of the run, due to the design of the lubricating system and action of the engine, it was not possible to have analyses made of the used oil. * * * While barometer and humidity were variable over the series of runs, the temperature was comparatively constant—at least varied only through a narrow range, which would not materially affect engine operation. As previously noted, this was desired, for the reason that the engine was air-cooled, and accordingly there was an approximation of equal radiation effects in all instances. * * * Comparing the engine conditions at the close of the run, it was observed that with oil C-1 and oil C-5 the deposits were thin and even, but very adhesive and gummy in nature. As the percentage of castor was reduced in oils used on tests C-2, C-3 and C-4, inclusive, the nature of the deposit became less adhesive, and flaky in place of gummy. In the case of the 10 per cent. compound, test C-4, the deposits on the outside of the valves were negligible, and the slight formation on the cylinder-head and valves was soft and sooty, to the extent that it was readily removed with a cloth. However, with the drop in percentage of vegetable oil, there was a tendency of the carbon to build up in the centre of the piston heads in place of the even deposits; but, as already mentioned, it was flaky and easily removed. A trial was made with a mineral oil following the runs with the compounded oil, which was unsuccessful, and indicated that engines of this type cannot be satisfactorily operated on mineral oils without a percentage of vegetable compound."

ABSORPTION OF GASOLINE BY CASTOR OIL.—The absorption of gasoline by castor oil increases with the density and boiling-point of the gasoline. Castor oil will absorb 100 per cent. or more of 57° Baumé gasoline and a very small percentage of casinghead. A straight mineral oil, such as would be used on airplane motors, will absorb gasoline of all densities and boiling points in unlimited percentages.

LIBERTY AERO OIL—SPECIFICATIONS AND USE.—(Report, Equipment Division, Signal Corps, U. S. Army): "Liberty aero oil shall be a pure, highly refined hydrocarbon product, neutral in action, and should not show the presence of acid, sulphur, charring or wax-like constituents, naphthenic acids, sulphonated oils, soap, resin, or carry constituents which would indicate adulteration or a lack of proper refining. This oil shall be either a straight-run product or a blend of heavy and light viscosity oils, suitable in every way for the entire lubrication of stationary cylinder aero engines under all conditions. The viscosity of the finished oil at 212° Fahr. on the Saybolt Universal Viscosimeter shall be from 85 to 90 seconds for the low specific gravity oils and from 70 to 75 seconds for the high specific gravity oils. High flash, if anything,

seems to indicate something of a detrimental nature, and in making this oil, refiners can work to viscosity, using stocks possessing good value, based upon other considerations than the flash- and fire-points. The pour test for the low specific gravity oils shall not be over 40° Fahr., and for the high specific gravity oils not over 15° Fahr. The oils shall not contain or show a carbon residue of over 1.5 per cent. by the modified Conradson method, and the nature of the carbon shall be loose and flaky, and shall easily break up in the crucible."

"It is necessary, in order to balance all factors, to use a very extra heavy oil, and this oil should be placed in the engine after it has been heated to 160° Fahr. In order to more readily accomplish the result for which hot oil is put in the engine, hot water should also be put in the hot-water circulating system. The heating of the engine is a practice that should be established summer and winter. * * * All oils should be removed from the engines every night, and should be sent to the reclaimer for the removal of the residue and the heavy ends of gasoline."

***GUIDE WIRES, AIRPLANE, PROTECTION OF.**—Guide wires and similar exposed parts involving ferros metals must be protected from rusting in airplane use. Enamels and enamel painting are not satisfactory protective mediums, as their protection is only temporary and they lack flexibility and elasticity. For protecting guide wires, etc., a heavy viscous cable or chain lubricant is recommended (see index). This lubricant should be a petroleum product, free from vegetable or animal oil or residue or fats of any kind, and free from fillers, talc, resin, tar, etc. The viscosity, Saybolt, at 212° Fahr. should be between 900 and 1100 seconds. It should be removable with kerosene. It should have high adhesiveness, and when applied to polished steel should protect the surface for at least 30 days from mechanical vapors, the action of salt or fresh water and from the action of water containing 10 to 25 per cent. of sulphuric acid at 60° Fahr. It must not crack, peel or chip at low atmospheric temperatures for a period of 60 days when applied to wire ropes, and when applied hot to the outside of a one-inch wire rope the lubricant should penetrate to and be absorbed by the fibre core.

For treating guide wires and cables, the lubricant described should be heated until thin, the cable or parts be immersed in the hot lubricant for sufficient time to permit it to reach the same temperature as the lubricant. This will permit penetration between the strands or bearing surfaces. The parts or cables should then be removed and allowed to drain. Before immersion the parts should be thoroughly cleaned and all traces of grease or light oil removed, in order not to impair the adhesiveness of the lubricant. In the case of cables, the protection desired is not on the outer surfaces, since failure of cables takes place in the interior, due to rusting and rotting of the core; also the interior of the cable is the point where greatest friction occurs.

GUN OIL.—Specification (Signal Corps, U. S. Army, Specification No. A-3, 507, extract from).

General

1. This specification covers the requirements of the Signal Corps for gun oil to be used for the following purposes and where airplane machine-gun oil (Specification No. 3503) is not required:

* From a report of the Aeronautical Division, Signal Corps, U. S. Army.

For cleaning and oiling guns and small arms. * * *

For lubrication of the compressor and expander cylinders of ice machines.

For lubrication of pneumatic tools.

For hydraulic systems.

Physical Properties and Tests

2. The oil must be a straight-run, highly refined and highly filtered mineral oil, suitable in every way for the uses listed in paragraph 1.

3. The oil must be a petroleum product only, free from vegetable or animal oils or fats of any kind and entirely free from moisture.

4. Viscosity: The viscosity must be within the following limits when the oil is tested in a Saybolt Universal Viscosimeter at 100° Fahr., 95 seconds to 105 seconds.

5. Flash-point: The flash-point of the oil must not be less than 300° Fahr. in a Cleveland Open Cup.

6. Pour test: One ounce of the oil must not congeal in a 4-ounce standard sample bottle at 5° below zero, Fahr.

7. Carbon: The carbon residue must not be more than 0.03 per cent. by the Conradson method.

8. Acidity: The oil must not show an acid reaction of more than 0.03 per cent. calculated as SO_3., and must not gum or corrode metals under any conditions.

AIRPLANE MACHINE-GUN OIL.—Specification (Signal Corps, U. S. Army, Specification 3503-A, extract from):

General

1. This specification covers the requirements of the Signal Corps for gun oil for lubrication of machine guns on airplanes, for the c.c. interrupter gears and for gun oil for cleaning and oiling machine guns and small arms.

Physical Properties and Tests

2. The oil must be a highly refined, highly filtered, straight-run mineral oil, suitable in every way for the uses specified in paragraph 1. It must be a pure petroleum product, without the addition of vegetable or animal oils or fats of any kind and must contain no moisture.

3. The oil must be free from acids and from any material which might gum or corrode metals under any conditions.

4. Viscosity: The viscosity when the oil is tested in a Saybolt Universal Viscosimeter at 100° Fahr. shall be as follows: 70 seconds to 95 seconds.

5. Acidity: The acidity of the oil must not be more than 0.03 per cent., calculated at SO^3.

6. Carbon: The carbon residue must not be more than 0.03 per cent. when determined by the Conradson method.

7. Pour test: One ounce of the oil must not congeal in a standard 4-ounce sample bottle at 45° below zero Fahr. * * *

SIGNAL OIL.—(Bureau of Aircraft Production, U. S. Army. Specification 3516, extract from):

General

1. This specification covers the requirements of the Bureau of Aircraft Production for an oil to be burned in such devices as are subject to severe jars, which would extinguish a flame resulting from burning a pure mineral oil. Also for safety and to meet the statutes that require a 300° fire test for oils used for illumination on passenger conveyances, including steamboats.

Physical Properties and Tests

2. Composition: The oil must be a compound of prime lard oil or refined peanut oil, with 300° fire test burning oil, commonly known as Mineral Seal.

3. Percentage: The oil must contain not less than 32 per cent. by weight of the fatty oil.

4. Burning Test: The oil must burn freely in the regulation trainman's lantern, using a flat wick for 12 hours, without adjustment after the first hour, without serious drop in flame and without leaving a hard crust on the wick. After this observation the lantern must be allowed to burn itself out. An oil that will not burn entirely from the font, with reasonable drop in flame, will be subject to rejection as having poor burning qualities.

5. Acidity: The oil must be free from mineral acid, and must not contain more free fatty acid than can be neutralized with 1.0 milligram of caustic potash for each 1.0 gram of oil.

6. Pour Test: One ounce of the oil must not congeal in a standard 4-ounce sample bottle when exposed to a temperature of 25° Fahr.

7. The oil must not be cloudy from the presence of suspended matter of any kind.

MOTOR FUELS FOR AIRPLANE MOTORS.—(Report, Signal Corps, U. S. Army, 1917):

A number of tests were run by the Signal Corps, U. S. Army, to determine the effect of using different grades of gasoline for operation of aeronautical engines. The tests were made during December. The engine used was a Hall-Scott motor:

Type: A7a.
Number of cylinders: 4.
Size:
  Bore: 5 1/4-inch.
  Stroke: 7-inch.
Rated H. P.: 100.
Rated R. P. M.: 1400.
Carburetor: Zenith.
Ignition: Dixie.
Oiling system: Pressure.
Capacity crank-case: 4 gallons.
Material:
  Cylinder: Steel lining.
  Crank-case: Aluminum.
  Pistons: Aluminum.
Weight per rated H. P.: 4.32 pounds. (Includes hot-air stove, hot-air pipe to carburetor, exhaust pipes and propeller hub, but not the front propeller flange or bolts.)

The report states that the gasoline tested covers a wide range of characteristics, though the grades are numerically few. They include ideal gasoline of high volatility and narrow distillation range, down to the commercial product of to-day as supplied for motor-boat use. The grades noted as Signal Corps brands were distilled especially for these tests, according to specifications corresponding to the requirements of the French and German Governments. * * *

Brand	Gravity		Range of Distillation
	Baumé	Specific	
Motor Boat Gas.	61.3	.7320	135–365° F.
Signal Corps No. 1	75.2	.6823	110–250° F. (German)
Signal Corps No. 2	63.6	.7225	140–292° F. (French)

"Each run was of five hours' duration, the first half hour of which was made with the throttle wide open and the remaining 4 1/2 hours at an output of approximately 90 per cent. of the rated capacity of the machine. * * * Samples of oil were drawn from the lubricating oil system at the end of every hour, prior to the addition of fresh oil which might be required at that time. * * * Since the effect of gasoline absorption of a lubricating oil is shown most consistently by the change in the viscosity, and believing there is a definite relationship between the distillation range of the fuel, and this change in the lubricant, due to contamination with gasoline, this feature was especially studied. * * * It is of interest to know that during these tests in which were used different grades of gasoline with varied ranges of distillation, there was no apparent difference in the operation of the engine nor in the ease with which it could be started up. * * *"

GASOLINE TESTS

(From Report, Signal Corps, Aeronautical Section, U. S. Army.)

Test No.	A-1		A-2		A-3	
	Start	Finish	Start	Finish	Start	Finish
Specific gravity	.9440	.9446	.9449	.9457	.9481	.9456
Baumé gravity	18.30	18.22	18.17	18.03	18.30	18.06
Flash-point (° F.)	405	210	395	220	385	246
Fire-point (° F.)	480	470	470	456	470	460
Pour test (° F.)	9 below 0°		9 below 0°		10 below 0°	
Saybolt viscosity, 100° F.	1703	1567	1680	1735	1700	1787
Saybolt viscosity, 130° F.	528	521	530	535	532	588
Saybolt viscosity, 212° F.	82	82	77	76	80	79
Saybolt viscosity, 300° F.	43	43	45	45	43	43
Conradson carbon, per cent.	0.36	1.11	0.36	0.92	0.42	0.97
Conradson carbon, nature	Loose flaky	Hard granular adhesive	Loose flaky	Hard granular adhesive	Loose flaky	Hard granular adhesive
Carbon (Waters)	0.16	1.03	0.24	0.89	0.23	1.04
Acid number	0.07	0.15	0.07	0.15	0.08	. 0.15
H_2O per cent.	0	0	0	0	0	0
Color	Red	Black	Red	Black	Red	Black
Demulsibility	86	0	120	0	....	0
Residue, volume per cent.	....	30	....	26	....	22
Residue, weight per cent.	....	.60	....	.48	....	.49
Ash	....	0.03	....	0.01	....	Trace
Fe_2O_3						
Gasoline, per cent. by evaporation	....	0.55	....	0.44	....	0.19
Gasoline, per cent. by distillation.	....	1.0	....	0.52	....	0.50
Barometer	30.74		30.15		30.09	
Humidity	0.003672		0.003578		0.003008	
Weather condition	Clear		Snowing		Cloudy, snow	
Temperature (dry bulb)	....		32.1		41.1	
Duration of run	5 hours		5 hours		4 hours, 53 mins.	
Average R. P. M.	1336.8		1336.1		1337.9	
Average H. P. developed	97.2		93.3		94.9	
Gasoline, lb. per hour	51.43		52.48		52.2	
Gasoline, lb./B. H. P./hr.	0.5293		0.5635		0.5503	
Lubricating oil, lb. per hour	4.18		4.05		4.106	
Lubricating oil, gal. per hour	0.53		0.514		0.52	
Lubricating oil, lb./ B. H. P./hr.	0.04275		0.04299		0.04186	
Lubricating oil, gal./B. H. P /hr.	0.00543		0.00543		0.00529	
Temperature oil, end of run	150		156		152.0	

Tests of Lubricating Oil Used.

Note.—Same kind of motor oil used all tests. Hall-Scott motor with 100 H. P. rated H. P.

Note.—Figures based on readings of barometer, thermometer, R. P. M., gasoline and oil consumption, are average of 4½ hour run at approximately 90% full load.

Note.—Test A-1. Gasoline used Navy motor.
Test A-2. Gasoline used Signal Corps No. 2.
Test A-3. Gasoline used Signal Corps No. 1.

Note.—See page 568.

GRAVITY AND DISTILLATION TEMPERATURES OF GASOLINES USED IN TEST SHOWN ON PAGE 569

(Taken from Report, Aeronautical Section, Signal Corps, U. S. Army.)

Test No.	A-1	A-2		A-3	
Sample from	Tank during test	Tank during test	Tank end of test	Tank during test	Tank end of test
Specific gravity at 15.5° C.	0.7320	0.7225	0.7234	0.6823	0.7440
Baumé gravity at 15.5° C.	61.26	63.78	63.53	75.78	75.78
Distillation (° F.)					
1st drop	135	140	168	110	110
5 per cent. (vol.)	170	175	176	126	125
10 per cent.	185	180	184	132	131
15 per cent.	195	185	186	138	136
20 per cent.	204	186	188	139	138
25 per cent.	208	190	192	143	141
30 per cent.	216	192	195	148	145
35 per cent.	223	194	194	153	148
40 per cent.	228	198	200	158	152
45 per cent.	235	200	203	162	155
50 per cent.	240	205	207	167	150
55 per cent.	246	206	210	170	164
60 per cent.	252	210	213	174	168
65 per cent.	260	214	217	180	172
70 per cent.	270	220	220	185	178
75 per cent.	280	222	224	190	182
80 per cent.	292	230	232	198	188
85 per cent.	306	236	238	210	194
90 per cent.	325	240	248	232	204
95 per cent.	358	262	268	240	220
100 per cent.	385	292	294	250	235

AVIATION GASOLINE (FIGHTING).—Specification: (Bureau of Aircraft Production, U. S. Army, Specification No. 3513, extract from):

Color

1. The color shall be water-white until inspected by a representative of the Quartermaster Corps.

The manufacturer shall then color the gasoline in the containers a shade of red to match a 4-ounce standard color sample to be furnished by the buyer.

2. Coloring material: The coloring material used shall be an aniline dye soluble in petroleum naphthas.

Foreign Matter

3. The gasoline must be free from acid, undissolved water and suspended matter.

4. Acid test: Shake 10 c.c. of gasoline with 5 c.c. of pure water and test the water with blue litmus paper.

5. Water and suspended matter would be in evidence in the test for color.

Doctor Test

6. The gasoline must show a negative result when subjected to the doctor test, which is conducted as follows:

(*a*) Preparation of reagents: Sodium plumbite or "doctor solution": Dissolve approximately 125 grams of sodium hydroxide ($NaOH$) in a liter of distilled water. Add 60 to 70 grams of litharge (PbO) and shake vigorously for 15 to 30 minutes, or let stand with occasional shaking for at least a day. Allow to settle and decant or siphon off the clear liquid. If the solution does not settle clear it may be filtered through an asbestos mat. The solution should be kept in a bottle tightly stoppered with a cork. Obtain pure flowers of sulphur.

(*b*) Making of test: Shake vigorously together two volumes of gasoline and one volume of the "doctor solution" (10 c.c. of gasoline and 5 c.c. of "doctor solution" in an ordinary test tube; or proportional quantities in a 4-ounce oil sample bottle may be conveniently used). After shaking for about 15 seconds, a small pinch of pure flowers of sulphur should be added, and the tube again shaken for 15 seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface separating the gasoline from the "doctor solution."

(*c*) Interpretation of results: If the gasoline is discolored, or if the sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive and the gasoline condemned as "sour." If the liquid remains unchanged in color, and if the sulphur film is bright yellow or only slightly discolored with gray or flecked with black, the test shall be reported as negative and the gasoline considered "sweet."

Corrosion and Gumming Test

7. The gasoline, when subjected to the following corrosion test, must show no black corrosion and no weighable amount of gum:

(*a*) Directions for making test: The apparatus used in making this test consists of a freshly polished hemispherical dish of spun copper, approximately 3 1/2 inches in diameter. Fill the dish to within 3/8-inch of the top with the gasoline to be examined and place the dish upon a steam bath. Leave the dish on the steam bath until all volatile portions have disappeared. If the gasoline contains any dissolved elementary sulphur, the bottom of the dish will be blackened. If the gasoline contains undesirable gum-forming constituents there will be a weighable amount of gum deposited in the dish. Acid residues will show as gum in this test.

(*b*) Interpretation of results—Corrosion: It is specified that no black deposit shall be formed. This wording is intended to admit gasolines which contain so small a quantity of sulphur that the deposit is only gray or peacock-colored.

Gum: It is specified that there shall be no weighable amount of gum. The intention is to reject gasolines that show an amount that can be readily weighed in this style of dish.

Volatility or Distillation Range

8. When 5 per cent. of the sample has been recovered in the graduated receiver, the thermometer must not read more than 75° C. (158° F.), or less than 60° C. (140° F.).

When 50 per cent. has been recovered in the receiver, the thermometer must not read more than 95° C. (203° F.).

When 90 per cent. has been recovered in the receiver, the thermometer must not read more than 113° C. (235° F.).

When 96 per cent. has been recovered in the receiver, the thermometer must not read more than 125° C. (257° F.).

9. At least 96 per cent. must be recovered in the receiver from the distillation.

The distillation loss must not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

10. The distillation method and apparatus shall conform to those outlined and described in Bureau of Mines Technical Paper No. 166, entitled "Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications."

Method of Determining Quantity

11. The number of gallons of gasoline delivered shall be determined by weight. A standard gallon shall be defined as 231 cubic inches at 60° Fahr.

AVIATION GASOLINE (DOMESTIC).—Specification: (Bureau of Aircraft Production, U. S. Army, Specification No. 3511-B, extract from):

Color

1. The color shall be water-white.
2. Test for color: Inspection of a column in a standard 4-ounce oil sample bottle.

Foreign Matter

3. The gasoline must be free from acid, undissolved water and suspended matter.
4. Acid test: Shake 10 c.c. of gasoline with 5 c.c. of pure water and test the water with blue litmus paper.
5. Water and suspended matter would be in evidence in the test for color.

Doctor Test

6. The gasoline must show a negative result when subjected to the doctor test, which is conducted as follows:

(*a*) Preparation of reagents: Sodium plumbite or "doctor solution": Dissolve approximately 125 grams of sodium hydroxide ($NaOH$) in a liter of distilled water. Add 60 to 70 grams of litharge (PbO) and shake vigorously for 15 to 30 minutes, or let stand with an occasional shaking for at least a day. Allow to settle and decant or siphon off the clear liquid. If the solution does not settle clear it may be filtered through an asbestos mat. The solution should be kept in a bottle tightly stoppered with a cork. Obtain pure flowers of sulphur.

(*b*) Making the test: Shake vigorously together two volumes of gasoline and one volume of the "doctor solution" (10 c.c. of gasoline and 5 c.c. of "doctor solution" in an ordinary test tube; or proportional quantities in a 4-ounce oil sample bottle may be conveniently used). After shaking for about 15 seconds, a small pinch of pure flowers of sulphur should be added and the tube again shaken for 15 seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface separating the gasoline from the "doctor solution."

(*c*) Interpretation of results: If the gasoline is discolored, or if the sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive, and the gasoline condemned as "sour." If the liquid remains unchanged in color, and if the sulphur film is bright yellow or only slightly discolored with gray or flecked with black, the test shall be reported as negative, and the gasoline considered "sweet."

Corrosion and Gumming Test

7. The gasoline, when subjected to the following corrosion test, must show no black corrosion and no weighable amount of gum.

(*a*) Directions for making test: The apparatus used in this test consists of a freshly polished hemispherical dish of spun copper, approximately 3 1/2 inches in diameter.

Fill this dish to within 3/8-inch of the top with the gasoline to be examined and place the dish upon a steam bath. Leave the dish on the steam bath until all volatile portions have disappeared. If the gasoline contains any dissolved elementary sulphur the bottom of the dish will be blackened. If the gasoline contains any undesirable gum-forming constituents there will be a weighable amount of gum deposited on the dish. Acid residues will show as gum in this test.

(*b*) Interpretation of results—Corrosion: It is specified that no black deposit shall be formed. This wording is intended to admit gasolines that have so small a quantity of sulphur that the deposit is only gray or peacock-colored.

Gum: It is specified that there shall be no weighable amount of gum. The intention is to refuse admittance to gasolines that show an amount that can be readily weighed in this style of dish.

Volatility or Distillation Range

8. When 5 per cent. of the sample has been recovered in the graduated receiver, the thermometer must not read more than 75° C. (167° F.), or less than 50° C. (122° F.).

When 50 per cent. has been recovered in the receiver, the thermometer must not read more than 105° C. (221° F.).

When 90 per cent. has been recovered in the receiver, the thermometer must not read more than 155° C. (311° F.).

When 96 per cent. has been recovered in the receiver, the thermometer must not read more than 175° C. (347° F.).

9. At least 96 per cent. must be recovered in the receiver from distillation.

The distillation loss must not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

10. The distillation method and apparatus shall conform to those outlined and described in Bureau of Mines Technical Paper No. 166, entitled "Motor Gasoline, Properties, Laboratory Methods of Testing, and Practical Specifications."

Method of Determining Quantity

11. The number of gallons delivered shall be determined by weight. A standard gallon shall be defined as 231 cubic inches at 60° Fahr.

AVIATION GASOLINE (EXPORT).—Specification: (Bureau of Aircraft Production, U. S. Army, Specification No. 3512, extract from):

Color

1. The color shall be water-white.
2. Test for color: Inspection of a column in a standard 4-ounce sample bottle.

Foreign Matter

3. The gasoline must be free from acid, undissolved water and suspended matter.
4. Acid test: Shake 10 c.c. of gasoline with 5 c.c. of pure water and test the water with blue litmus paper.
5. Water and suspended matter would be in evidence in the test for color.

Doctor Test

6. The gasoline must show a negative result when subjected to the doctor test, which is conducted as follows:

(a) Preparation of reagents: Sodium plumbite or " doctor solution ": Dissolve approximately 125 grams of sodium hydroxide ($NaOH$) in a liter of distilled water. Add 60 to 70 grams of litharge (PbO) and shake vigorously for 15 to 30 minutes, or let stand with occasional shaking for at least a day. Allow to settle and decant or siphon off the clear liquid. If the solution does not settle clear, it may be filtered through an asbestos mat. The solution should be kept in a bottle tightly stoppered with a cork. Obtain pure flowers of sulphur.

(*b*) Making of test: Shake vigorously together two volumes of gasoline and one volume of the " doctor solution " (10 c.c. of gasoline and 5 c.c. of " doctor solution " in an ordinary test tube; or proportional quantities in a 4-ounce oil sample bottle may be conveniently used). After shaking for about 15 seconds, a small pinch of pure flowers of sulphur should be added and the tube again shaken for 15 seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface separating the gasoline from the " doctor solution."

(*c*) Interpretation of results: If the gasoline is discolored, or if the sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive, and the gasoline condemned as " sour." If the liquid remains unchanged in color, and if the sulphur film is bright yellow or only slightly discolored with gray or flecked with black, the test shall be reported as negative, and the gasoline considered " sweet."

Corrosion and Gumming Test

7. The gasoline, when subjected to the following corrosion test, must show no black corrosion and no weighable amount of gum:

(*a*) Directions for making test: The apparatus used in this test consists of a freshly polished hemispherical dish of spun copper, approximately 3 1/2 inches in diameter. Fill this dish to within 3/8-inch of the top with the gasoline to be examined, and place the dish upon a steam bath. Leave the dish on the steam bath until all volatile portions have disappeared. If the gasoline contains any dissolved elementary sulphur, the bottom of the dish will be blackened. If the gasoline contains undesirable gum-forming constituents, there will be a weighable amount of gum deposited on the dish. Acid residues will show as gum in this test.

(*b*) Interpretation of results—Corrosion: It is specified that no black deposit shall be formed. This wording is intended to admit gasolines that have so small a quantity of sulphur that the deposit is only gray or peacock-colored.

Gum: It is specified that there shall be no weighable amount of gum. The intention is to refuse admittance to gasolines that show an amount that can be readily weighed in this style of dish.

Volatility or Distillation Range

8. When 5 per cent. of the sample has been recovered in the graduated receiver, the thermometer must not read more than 65° C. (149° F.); or less than 50° C. (122° F.).

When 50 per cent. has been recovered in the receiver, the thermometer must not read more than 95° C. (203° F.).

When 90 per cent. has been recovered in the receiver, the thermometer must not read more than 125° C. (257° F.).

When 96 per cent. has been recovered in the receiver, the thermometer must not read more than 150° C. (302° F.).

9. At least 96 per cent. must be recovered in the receiver from the distillation.

The distillation loss must not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

10. The distillation method and apparatus shall conform to those out-
The distillation method and apparatus shall conform to those out-
lined and described in Bureau of Mines Technical Paper No. 166, entitled "Motor Gasoline, Properties, Laboratory Methods of Testing, and Practical Specifications."

Method of Determining Quantity

11. The number of gallons of gasoline delivered shall be determined by weight. A standard gallon shall be defined as 231 cubic inches at 60° Fahr.

SUMMARY OF SPECIFICATION DATA FOR AIRPLANE ENGINE LUBRICATION * (*Continued*)

Kind of Oil	Castor	Liberty Aero		Motor oil for gas engines			Airplane mach. gun	Gun Oil	Trans. Lubricant	Comp. Trans. Lubricant	Medium Cup Grease
		High sp. gr.	Low sp. gr.	Light	Medium	Heavy					
Specification No.	3500–A	3501		3502–A			3503–A	3507–A	3504	3505–A	3506
Specific gr., 60° F.	0.959–0.968	Above 0.910	Below 0.910								
Baumé gr., 60° F.	16.05–14.7	Below 24	Above 24								
Viscosity at 212° F.	95	70–75	85–90	......	......	......	......	......	195–220	70–120	
Viscosity at 100° F.	....	....	....	170–230	270–330	470–530	70–95	95–105	....	Min. oil used 180 at 100° F.	Min. oil used 180 at 100° F.
Cold test, Fahr.	−0°	15°	40°	25°	30°	40°	−45°	−5°	....	10°	
Flash, Fahr.	450°	350°	350°	....	......	....	....	300°	....	....	Heat test 212° F., must not separate.
Carbon, per cent.	....	1.5	1.5	0.2	0.4	0.6	0.03	0.03	....	....	Ash, 2 per cent.
Acidity, per cent.	1.5	Neutral	Neutral	.....	......	.....	0.03	0.03	....	2	Must not attack copper, 48 hours.
Moisture	Free	Free	Free	.....	......	.....	Free	Free	....	1½	1%–3%
Compound, per cent.	Free of resin, cottonseed oil	Free of sulphurates, soap, resin, etc.		.....	......	.....	Free of anything but mineral oil	Free of anything but mineral oil	Free of fillers and a straight petroleum product	Lime soda, lead soap base, made from animal, vegetable or fish oil	15–20 per cent. of tallow, neatsfoot, lard or horse oil.
Miscellaneous	Sol. in alcohol, Iod., 80–90; sap., 176–187 (4 vol.)	Emulsion test 180° F.		Emulsion test 180° F.			....	....	....	....	Free of fillers.

* NOTE. Aeronautical Division, Signal Corps, U. S. Army.

SUMMARY OF SPECIFICATION DATA FOR AIRPLANE ENGINE LUBRICATION* *(Continued)*

Kind of Oil	Gear, Chain, Wire-Rope Lubricant	Signal Oil	Motorcycle Oil	Kind of Oil	Aviation Gasoline			Kind of Oil	Kerosene
					Domestic	Export	Fighting		
Specification No.	3509–A	3516	3520	Specification number	3511–B	3512	3513	Specification	3517
Specific gr., 60° F. Baumé gr., 60° F.	....	....	....	Color	Water-white	Water-white	Water-white until inspected then colored red	Color	Water-white
Viscosity at 212° F.	900–1100	....	110	Distillation, 5 per cent.	75°–50° C.	65°–50° C.	70°–60° C.	Flash	100° F.
Cold test, Fahr...	....	25°	50°	Distillation, 50 per cent.	105° C.	95° C.	95° C.	Fire	140° F.
Flash test, Fahr.	....	Fire test 300° F.	....	Distillation, 90 per cent.	155° C.	125° C.	113° C.	Cold test	0° F.
Acidity, per cent.	....	Free of mineral acid, 0.5%	....	Distillation, 96 per cent.	175° C.	150° C.	125° C.	Sulphur	0.06 per cent.
Moisture, per cent.	....	Free	....	Foreign matter	Free	Free	Free	Burning test	Must be tested for 8 hours.
Compound, per cent.	Free of fats or fillers	Weight 32 per cent. prime lard or peanut	Free of compound	"Doctor" test	Negative	Negative	Negative		
Miscellaneous....	Adhesiveness, corrosion	....	Carbon 1.7 per cent.	Corrosion test	Negative	Negative	Negative		
Miscellaneous....	Drying and penetration tests must be made	Oil must not be cloudy from suspended matter	Emulsion test 180° F.	Acid test	Litmus	Litmus	Litmus		

* NOTE. Aeronautical Division, Signal Corps, U. S. Army.

SECTION 10d

AUTOMOBILES

VARIOUS TYPES OF LUBRICATING SYSTEMS.—Lubricating systems for the standard makes of motor cars may be divided into several distinct types, namely: Forced Feed, Splash Feed, Combination Force and Splash Feed, and various combinations of the above types with separate feeds or pumps.

SPLASH-FEED SYSTEM.—A typical type of splash-feed motor lubricating system is shown in Fig. 1, Sec. 10d, and is described as follows:

The crank-case and fly-wheel pit is used as a reservoir for the oil, which is put into it up to the level of the upper cock *B.* The fly-wheel *C* dips into the oil, as shown, and whirls it up against the top of the fly-wheel case and also out into the crank-case, spraying the back crank shaft bearing *D* and the crank bearings *E.* The oil splashed against the top of the fly-wheel case runs down the front sides and is led to the oil pipe *F,* which carries it to the front main bearing and flows it over the timing gears *G.* Each connecting rod *H* carries an oil dipper below it, as shown at *J.* These dippers are immersed in the oil, which is in the troughs *K,* each time the piston completes its downward stroke, and a splashing effect is produced, which serves to spread the oil in the form of a spray over the exposed parts of the motor.

The cylinder walls and piston surfaces are lubricated entirely by the spray of the oil. The wrist-pin bearings, cam-shaft bearings, crank-shaft bearings and crank-pin bearings are equipped with oil pockets, which catch the condensed spray and feed it to these bearings.

In this type of lubricating system it frequently happens, that due to the desire of the operator to carry an ample supply of oil, the level in the reservoir is carried too high, resulting in the splashing of an excessive amount of oil into the cylinders, which causes carbon deposits, smoking and waste.

SELECTION OF LUBRICANT.—The chief factors in the selection of a lubricant for automobile motors are: (1) The type of lubricating system, upon which depends the method of feeding the oil; (2) the type of cooling system, which factor has more or less effect upon the operating temperatures of the various parts of the motor.

In some rare cases the oil is fed with the fuel.

In those systems, which use a combination of splash and forced feed, the oil is pumped to the main bearings under pressure. Some of the oil is also pumped into a trough which runs through the crank-case, and from which the oil overflows to the connecting rod dipper troughs, from which it is splashed by the dippers to the cylinders, piston rings, crank-pin bearings and cam-shaft bearings.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: O[n] the margin of the text, beside the description of a process, lubricating requirements of a machine or other basis for making selection or recommendation, mark a number. On the data sheet oppo[-]site this number insert your brand name or oil, that meets these requirements, and the price, i[n] the proper spaces. This will give a complete handbook and price book in one, and if filled ou[t] properly will be a guide to one not familiar with the industrial uses of oil products, which wil[l] insure an accurate recommendation and greatly assist him. Space on the back of the shee[t] provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

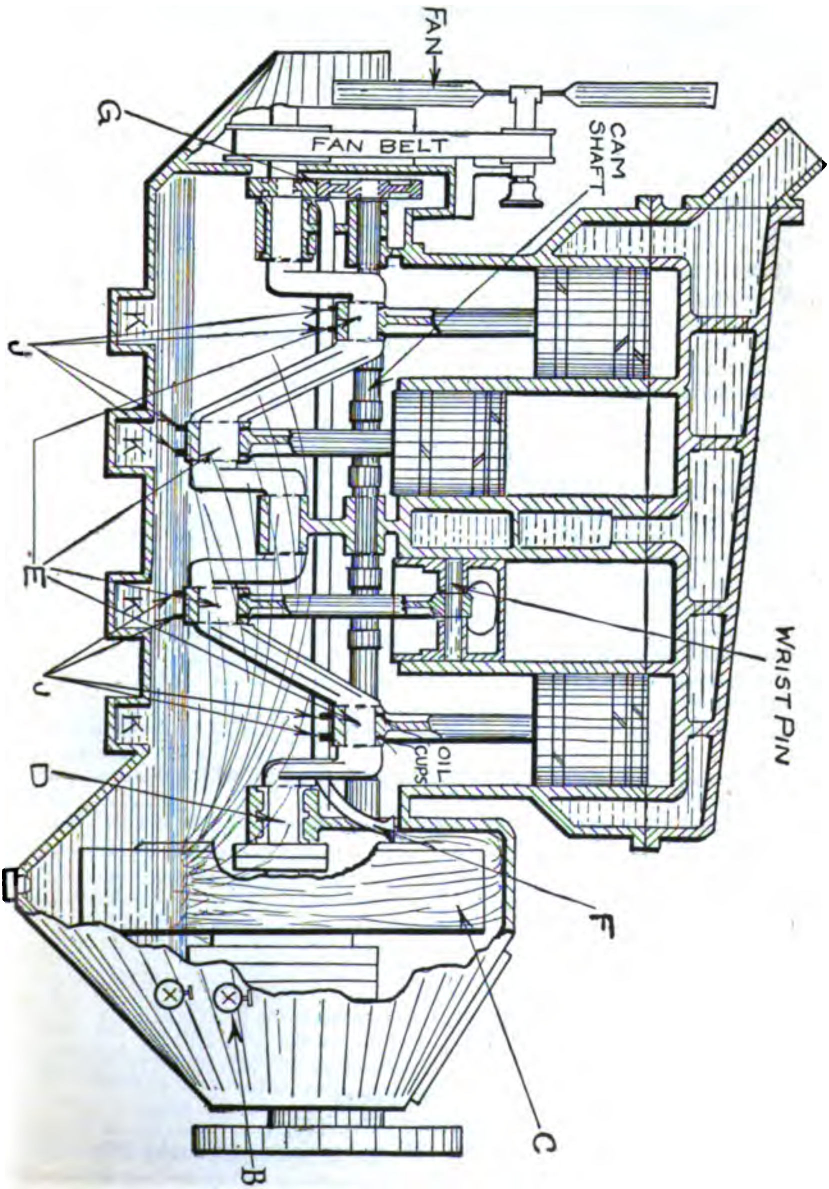

FIG. 1. SEC. 10*d*.—Automobile engine with splash-feed lubricating system.

PRESSURE-FEED SYSTEMS.—Fig. 2, Sec. 10d, shows a pressure lubricating system for an automobile engine.

The following table refers to the three lubricating systems as shown in Fig. 2, Sec. 10d, Fig. 3, Sec. 10d., and Fig. 4, Sec. 10d:

Main bearings	1
Main-bearing oil pockets	2
Connecting rods	3
Connecting-rod or crank-pin bearings	4
Connecting-rod bearing oil pockets	5
Connecting-rod splash dippers	6
Wrist pins	7
Wrist-pin bearings	8
Wrist-pin bearing oil pockets	9
Cam shaft	10
Cam-shaft bearings	11
Cam-shaft bearing oil pockets	12
Pistons	13
Piston rings	14
Timing gears	15
Timing-gear oil pockets	16
Oil (splash) troughs	17
Crank-case reservoir or sump	18
Oil reservoir	19
Oil reservoir filler cap	19^1
Oil strainer	20
Oil pump	21
Pet cocks or oil-level gauge	22
Crank-case drain plugs	23
Oil gauge (on cowl of dash)	24
Sight-feed adjustment screw, regulates flow of oil to rear main bearing (1)	24^1
Sight-feed adjustment screw, regulates flow of oil to front main bearing (1)	24^2
Sight-feed adjustment screw, regulates overflow to oil reservoir (19)	24^3
Pressure relief valve	25
Cylinders	26
Combustion chamber	27
Intake valves	28
Exhaust valves	29
Valve springs	30
Valve lifter rods	31
Intake ports	32
Exhaust ports	33
Spark plugs	34

OIL DUCTS

From pump to gauge (24) or relief valve (25)	*A*
From gauge (24) or relief valve (25) to bearings or troughs (17)	*B*
From pump to troughs (17)	*C*
Drilled through crank-shaft from main bearings (1) to connecting-rod bearings (4)	*D*

Tube from connecting-rod bearings (4) to wrist-pin bearings (8) .... *E*
Auxiliary feed direct to cylinders .... *F*
Overflow from sight feed (24) to oil reservoir (19) .... *G*
From relief valve to pressure gauge (24) .... *H*

In Fig. 2, Sec. 10d, is shown a sectional view of a pressure-feed system. Its operation may be described as follows: Oil is pumped to the main bearings (1), then it is carried by the ducts *D*, drilled through the crank-shaft to the connecting-rod bearings (4); from here part of the oil, still under pressure, flows through a tube *E* to the wrist-pin bearings (8). With

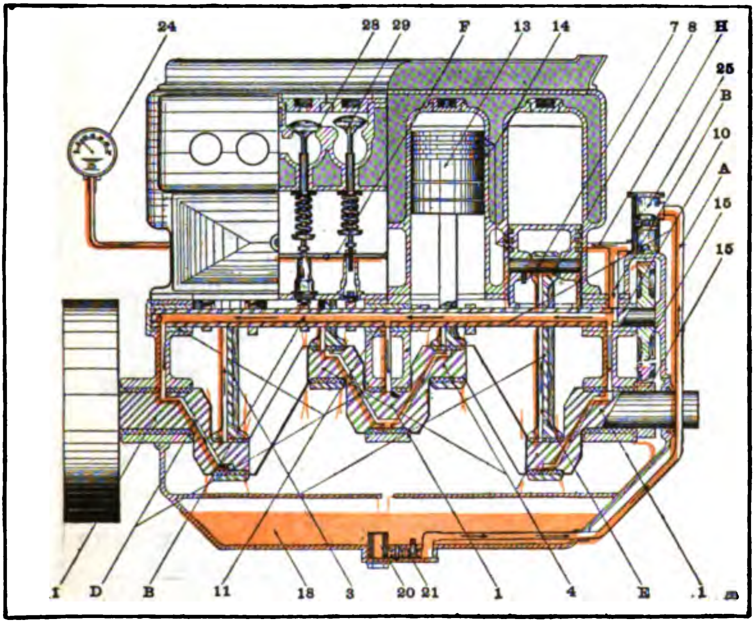

Fig. 2. Sec. 10*d*.—Automobile engine with pressure-feed lubricating system. (Courtesy The Atlantic Refining Co.)

some engines using this system a hollow cam-shaft acts as the distributing manifold; that is, the oil is first pumped to the cam-shaft, through which it flows to the main bearings.

Only part of the oil received at the connecting-rod bearing is fed to the wrist-pin bearing, the excess oil being forced out from between the bearing surfaces and thrown as a spray from the crank-shaft. For the average engine, the cylinder walls depend upon this spray for their lubrication, and in some engines the wrist-pin and cam-shaft bearings are also lubricated in the same manner.

SPLASH SYSTEM.—Fig. 3, Sec. 10d, shows a sectional view of an engine equipped with the pump-over and splash system of lubrication. With this system the oil is supplied to the crank-case or to individual pans (17), which are under each connecting-rod dipper (6). As each piston

makes a downward stroke these dippers dip into the oil and splash it against the walls of the crank-case, breaking it up into a fine mist or spray, which covers all the internal parts of the engine. Some of this spray collects in the oil pockets (2, 5, 9, 12, 16), which are located over each bearing, and from there passes through holes to the bearing surfaces. The cylinder walls also depend upon this spray for their lubrication.

One of the advantages of supplying the oil to the individual pans, as is the case in many engines, is that the oil level is kept constant, since the

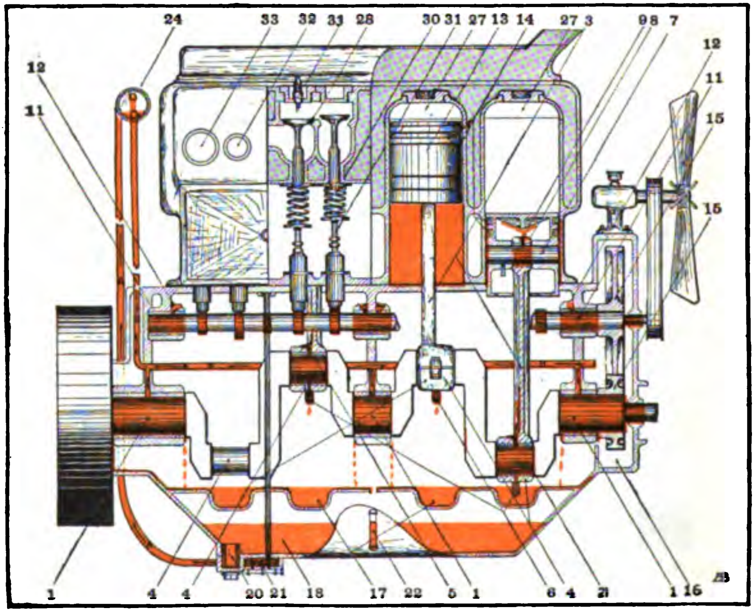

FIG. 3, SEC. 10*d*.—Automobile engine lubricated by the pump over and splash system. (Courtesy Atlantic Refining Co.)

pans are always kept filled to overflowing. In some variations of the splash system the oil is first supplied to one or more main bearings, from which it overflows to the pans and is splashed by the connecting-rod dippers to all the other moving parts.

In general, there are two methods of supplying the oil to the types of systems described:

(*a*) The crank-case or sump is filled to a predetermined level, which is usually indicated by a pet cock or oil gauge. From here the oil is pumped by means of a geared or plunger pump, or by centrifugal force of the fly-wheel, through a passage directly to the main bearings, as in the pressure-feed system described, or to the pans described in the splash system.

(*b*) A separate reservoir may be provided, which is filled with oil, and a plunger pump, or a series of them, supplies the oil to the bearings

or directly to the crank-case. This method keeps the oil in the crank-case at a constant level. A sectional view of this system is shown in Fig. 4, Sec. 10d.

PRESSURE-SYSTEM CONTROL.—Pressure-feed systems are usually equipped with a relief valve, by which the pressure on the oil flowing through the system can be regulated, and thus the supply of oil can be regulated.

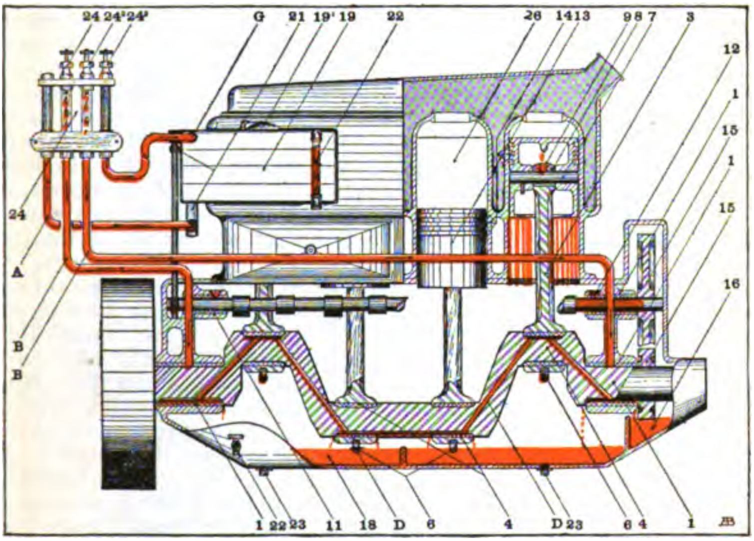

FIG. 4. SEC. 10*d*.—Automobile engine with outside reservoir for lubricating oil. (Courtesy Atlantic Refining Co.)

DEVELOPMENT OF LUBRICATING SYSTEMS, AMERICAN CARS.—(*Automotive Industries,* January 15, 1920):

The following table illustrates the trend of the types of engine lubricating systems in the average American car:

Type	Year									
	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911
Splash (per cent)	23.15	31.40	57.00	35.00	52.70	46.50	42.00	53.00	68.00	81.00
Splash—pressure (per cent)	43.52	39.20	21.60	35.00	23.35	16.00	39.00	32.00	20.00	....
Pressure (per cent)	33.33	29.40	26.70	30.00	23.35	37.50	18.00	14.00	10.00	19.00

The figures for 1920 may be compared to British car models, which showed 54.9 per cent. pressure and 45.1 per cent. circulating splash lubricating systems. The Continental passenger cars, for 1920, show 82.5 per cent. pressure feed, 16.8 per cent. circulating splash and 0.7 per cent. plain splash lubricating systems.

SLIDING-VALVE (KNIGHT) MOTOR.—Fig. 5, Sec. 10d, shows the method of lubricating the Knight slide-valve motor. The pump-over and splash system, as shown, is probably used more than any type for the lubrication for the Knight slide-valve engine. The connecting-rod troughs *D* are generally hinged, to permit being lowered as required, allowing the connecting-rod scoops or dippers to dip deeper into the troughs as the throttle is opened and the engine load increased, or less deeply as the throttle is closed and the load is lightened. These movable troughs are connected by means of bell cranks to the throttle rod opening the carburetor valve. This avoids surplus oil on the sleeves, pistons, etc. Grooves *J* are cut on the outside of both sleeves and holes are bored through the outer sleeves *V*. Oil is splashed onto the walls of the inner sleeves *X*, thus lubricating the inner sleeves, pistons and rings. Oil splashed onto the outer side of the outer sleeves, due to their reciprocating motion, is carried up the cylinder walls, thus effecting lubrication. Part of this oil passes through the holes bored in the outer sleeves and lubricates the outside of the inner sleeves. The connecting rods, which drive the inner and outer sleeves, are lubricated by oil splashed on them, which collects in holes in either end and feeds to the lower and upper bearings. In some Knight engines additional oil feeds to the extreme upper ends of the sleeves are provided, which are both hand and throttle operated. For the lubrication of these engines, an oil having a viscosity of about 85 at 212° Fahr. (P. B.) is recommended. This oil is generally known to the trade as "special heavy," being a grade between the usual "heavy" and "extra heavy" oils.

"V" ENGINES (EIGHT AND TWELVE CYLINDERS).—The forced-feed system of lubrication has been universally adopted for the lubrication of this type of engine, due to the different angular positions of the two cylinder blocks above the crank-shaft. The system delivers oil to the crank-pin bearings. For the lubrication of small-bore "V"-type engines, with cast-iron pistons, an oil having about 50 Saybolt viscosity at 212° Fahr. is recommended. These engines run at lower operating temperatures, due to greater exposure of the surfaces, to the water and air cooling, in the small-bore "V" engine, as compared to the vertical, larger bore, four- and six-cylinder engines.

For lubrication of "V" engines equipped with aluminum pistons, a heavier oil is recommended, which should run about 60 Saybolt viscosity at 212° Fahr. to avoid "piston slap" and leakage.

It is important in engines of small bore and lower operating temperatures that the piston rings be tight and that surplus oil be kept below the pistons, since the comparatively low operating temperatures will otherwise result in rapid carbonization taking place in the combustion chambers. Another feature is that in these small-bore engines a very small carbon deposit has a greater effect upon the compression and premature ignition than is the case with larger-bore engines.

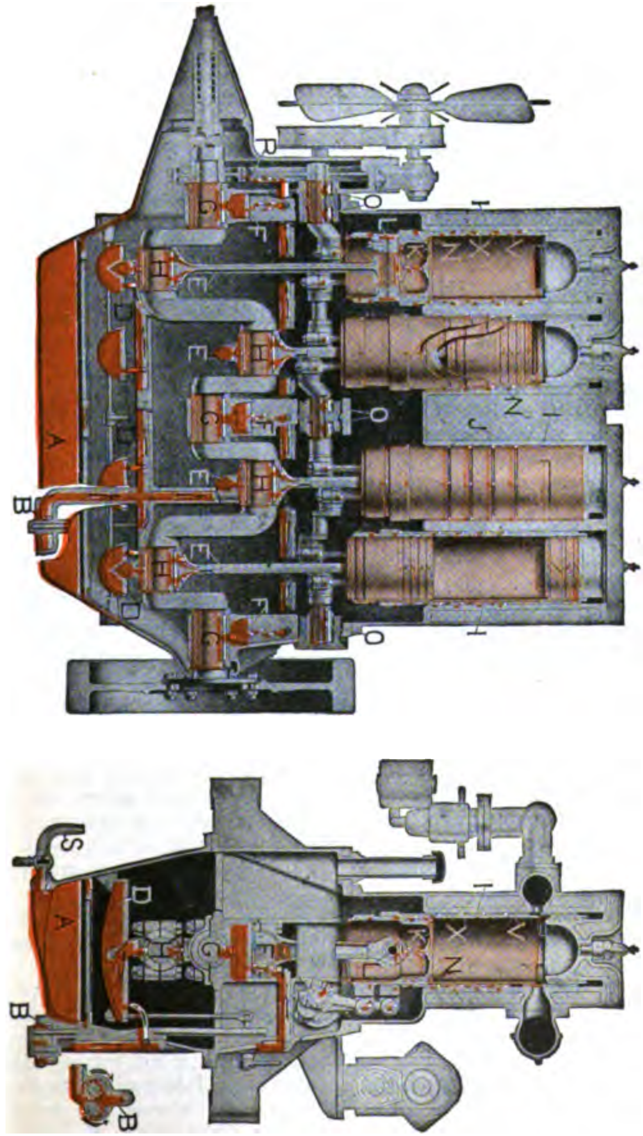

FIG. 5. SEC. 10d.—Lubrication of Knight slide valve motor. (Courtesy, Tidewater Oil Co.)

"V"-TYPE ENGINES, THERMOSTATS.—There are one or more thermostats fitted to the water-circulating systems in most "V"-type engines. The purpose of these thermostats is to block the free circulation of the water, which comes from the cooling jackets of the cylinders, until the cylinder walls and valve pockets have reached a sufficiently high temperature, so that the explosion chamber and cylinder walls will be maintained at a temperature that is high enough to produce efficient combustion of the fuel. They also have the effect of reducing carbon deposits, since by maintaining the temperature sufficiently high, the surplus oil will be flashed off, while if no thermostats were used the surplus oil would be only partially burned, due to a possible low temperature, and a residue would result.

ENGINE HEATING AND RADIATOR EFFECT.—It may be found that engine heating is not chargeable to poor lubrication, which is often given as the cause, but may be due to the effectiveness of the radiators, involving a tight construction capacity, or condition due to water, oil or dust deposits. It may also be found that with the various types of radiators, using either square or diamond or hexagonal sections, that, although the outside dimensions of the radiators may be the same, the volumetric capacities may differ considerably. One investigator found that the volumetric capacity, as between the square and the diamond or hexagonal section, varied from 35 quarts in the former to 23 1/4 quarts in the latter, and also the water passages in the square section pipe were found to be full size, while those in the other type showed many false sections.

LUBRICATION AND AUTOMOBILE-ENGINE DESIGN.—In order that the greatest possible mileage per gallon of lubricating oil be obtained, an automobile engine must be provided with tight piston rings and ample cooling facilities for the oil. The piston skirt must be sharp on the lower edge, and a shallow groove should be located just below the lower piston ring, and small holes drilled through the piston walls into the bottom of this groove.

Below the sump a settling basin, having a capacity of not less than 1/12 of the entire oil capacity and a depth of at least 3 inches, should be provided. This is intended as a settling basin for removing sediment in the oil returned to the sump. A filtering screen should have a mesh of about 1/16-inch, so that the free flow of the oil both in summer and winter will not be interfered with.

The sump should be provided with radiating fins on its outside surface to cool it, and the lower part of the crank-case should be exposed to the outer air.

The proper lubrication of motor equipment does not mean only the lubrication of the engine cylinders, nor does it mean the elimination of carbon only, but it does mean the complete lubrication of all the moving parts of the equipment. For instance, when a Ford car is filled with a heavy oil, there is placed in the crank-case a lubricating medium which will not circulate rapidly and build up a film between the moving parts fast enough to eliminate wear. As, for illustration, the Ford car is operated under the splash system, which means that as the fingers of the connecting rods slip down into the heavy oil, as described, a spray of heavy viscous oil is thrown upon the walls of the cylinders, the walls of

the crank-case, etc., instead of a fine spray being thrown, forming a mist that will settle uniformly on all moving parts and also travel in between the bearing surfaces at a high rate of speed, and furnish sufficient lubricant to eliminate friction and wear. In lubricating an internal-combustion motor, consideration must be taken of the pressure exerted upon the moving parts, as well as the heat conditions to which they are exposed. The pressure per square inch on a motor cylinder wall ranges from 40 to 90 pounds, and the cylinder walls and pistons are also subjected to heat conditions. The temperatures of the walls of the cylinders will range from 300° to 400° Fahr. When the inside temperature of the cylinder ranges from 260° to 400° Fahr., the water in the radiator is boiling, and, of course, the efficiency of the engine is greatly lowered. The temperature of the supporting surfaces of the cylinder averages about 350° Fahr., this temperature being maintained by the circulation of water in the water-jacket, and if the temperature runs higher, the water-jacket and radiator should be cleaned, so that the heat will travel through the metal and into the water more rapidly. The next point to consider is the wrist or piston pin, which carried a temperature from about 360° to 450° Fahr., and a pressure ranging from 750 to 1500 pounds per square inch. This means that the oil must reach these points as soon as possible.

Using too heavy an oil in the crank-case will, therefore, cause trouble, due to wrist or piston-pin wear, as the oil will not form a vapor, as would a lighter oil, and also the oil will work into the bearings too slowly. The next point of importance is the crank bearing. This bearing is not exposed to heat, but to a pressure ranging from 300 to 800 pounds per square inch, which means that the oil must get into this bearing area very fast in order to maintain the proper oil film. With too heavy an oil, and splash feed, this condition is impossible, and also, with force-feed lubrication and too heavy an oil, the pump cannot move the oil fast enough to supply the necessary lubrication. As, for illustration, the case of a Ford car, if too heavy an oil is used, since the lubrication of the front bearings and the timing gears is accomplished by the oil thrown from the flywheel, and conducted into a pipe near the flywheel, which in turn carries the oil the full length of the engine, this heavy oil cannot reach the front bearing in time to take up the load. In the average motor-car the motor is usually started, and the driver gets into his seat and is under way immediately, and it is, therefore, necessary that the oil supplied to the crank-case reach the moving parts as soon as the engine is turned over. In the usual motor-car engine the temperature at the ignition point in the cylinders ranges from 2800° to 3000° Fahr., and as the gases expand and the piston travels downward, the temperature is reduced until it reaches a point of about 900° Fahr., and in a good deal of motor equipment the exhaust temperature is around 1500° to 1800° Fahr. If the motor operates at the rate of 1800 to 2500 R. P. M., the period of time that the oil is exposed to this high temperature is very small. The oil on the walls of the cylinder is exposed to road dust, carbon, etc.

LUBRICATING DATA

GENERAL PASSENGER-CAR LUBRICATION.—Fig. 6, Sec. 10d, shows a section of a passenger car, illustrating the points of lubrication.

OPERATING TEMPERATURES.—Fig. 7, Sec. 10d, shows a sectional view of an engine, with the various operating temperatures of the engine brought out.

Summer and winter temperatures usually produce approximately a 50° Fahr. range in the temperatures of the oil leaving the bearings.

Automobile oils should flow freely at 25° Fahr. or better for general all-the-year use. However, the cold test need not be excessively low, as the only benefit obtained from a zero cold-test oil is easier cranking, since the engine heat quickly warms the oil after starting.

CARBON IN AUTOMOBILE CYLINDERS.—Road dust, metallic wear or too rich a mixture of gasoline are the usual causes of the so-called "carbon deposits," which are usually unjustly blamed upon the lubricating oil. There will always be some carbon formed in the cylinders of an internal-combustion engine, but it should be of such a nature that it will largely be removed with the exhaust.

An excess of oil in the crank-case will cause "carbon-deposit" troubles. The level of the oil should never be carried above the height indicated by the oil gauge. Too high a level will cause the oil to work up past the piston rings into the explosion space. Here the oil is partially burnt and deposits will result.

Chemical analysis of many "carbon deposits" has indicated that about 70 per cent. of these so-called "carbon deposits" found in the cylinders of automobiles consist of mineral matter. The analyses of these deposits show a large percentage of undecomposed oil, a small percentage of decomposed oil, a little free carbon, and, as before stated, about 60–70 per cent. mineral matter.

The mineral matter is hard and abrasive and causes wear between the piston rings and the cylinders. It is introduced into the cylinders during the suction stroke of the piston, which sucks in dust from the road mixed with air, and which eventually gets into the crank-case, where it is mixed with the oil and then is worked up into the cylinders. The heat of the explosions hardens the deposit, forming a "carbon-appearing scale." A small projection of this hard scale, remaining in the upper part of the cylinders, may become overheated and retain enough heat to ignite the incoming gas during the charging stroke. This condition is indicated by a pounding noise in the cylinder.

MISSING FIRE.—Missing in certain cylinders may be caused by small particles of the hard scale collecting on the spark plugs and forming a conductor for the current, thus short-circuiting the spark.

LOSS IN POWER AND COMPRESSION.—Loss in compression may be caused by small pieces of deposit working up under the exhaust valve and causing bad seating; this is indicated by a loss in power.

REMOVING THE DEPOSITS.—Often a small amount of kerosene poured through the priming cups, after the engine has been thoroughly heated, will loosen carbon deposit, if it is not too hard. After admitting the kerosene, allow the engine to stand overnight, and on restarting some of the deposit may be blown out with the exhaust. Oxygen is used to

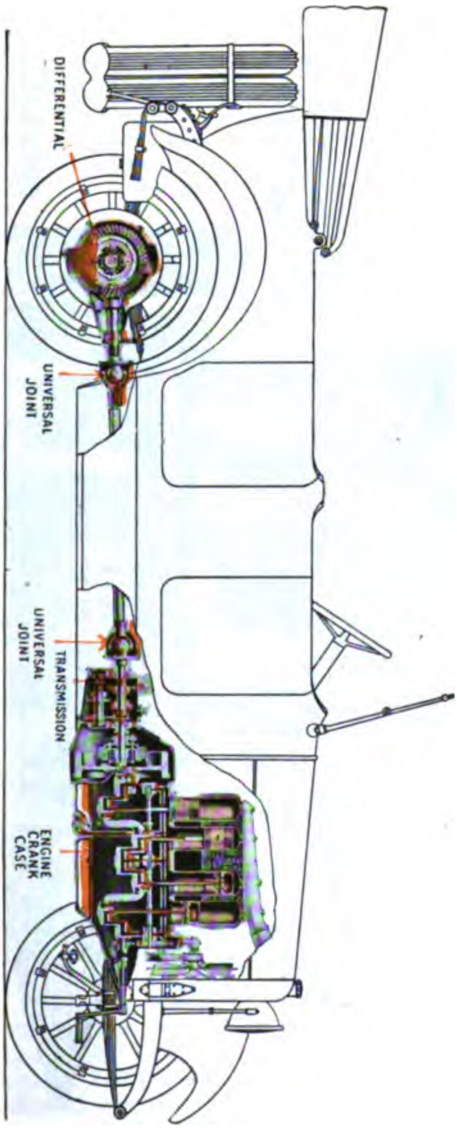

FIG. 6. SEC. 10d.—Section of passenger car showing points requiring continuous lubrication. (Courtesy, Tidewater Oil Co.)

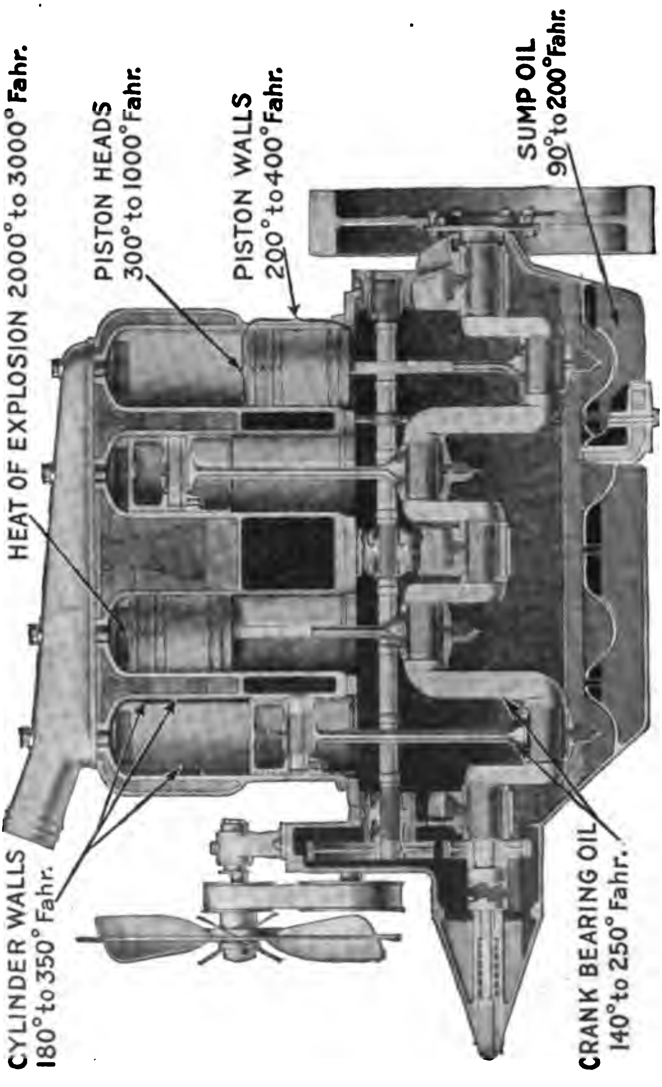

FIG. 7. SEC. 10*d*.—Operating temperatures of automobile engine parts. (Courtesy, Tidewater Oil Co.)

remove " carbon " by garages equipped with this process, and good results are obtained with it.

NOTES ON FILTERING GASOLINE THROUGH A STRAINER.—According to Mr. Ross Brooks, a fire chief of Oklahoma, gasoline should never be filtered through a funnel in which has been placed a chamois skin, as such a process while in common usage is very dangerous, due to the static electricity formed by the friction of the gasoline passing through the chamois. Mr. Brooks declares that many explosions of gasoline vapors, which have been believed to have been caused by a match, have really been caused by using chamois skin in the funnel. If the funnel is held suspended by the hand, or insulated from the tank so that no " ground " is formed, a spark will eventually leap from the funnel to the tank and an explosion may occur, if the proper mixture of air and vapor is present.

NOTES ON CYLINDER LUBRICATION.—It has been stated by some investigators that motor oils manufactured from paraffin-base crudes give a more objectionable carbon deposit in the cylinder than is produced by oils made from asphaltic-base crudes.

A careful practical working test to investigate this statement has indicated that the amount of carbon found in automobile engine cylinders averages the same for high or low viscosity oils made from either paraffin- or asphaltic-base crudes. The consistency of all motor-cylinder " carbon deposits," irrespective of the source of the oil, is about the same. The amount of carbon deposit produced depends upon the amount of oil actually reaching the upper part of the cylinder.

TYPES OF ENGINE FUEL FEED.—(*Automotive Industries*): According to the compiled data for the average American cars for 1920, 5.56 per cent. were equipped with gravity fuel feed, 7.40 per cent. with pressure fuel feed and 87.04 per cent. with vacuum fuel feed, as compared with the year 1915, when 57 per cent. were equipped with gravity feed, 0.50 per cent. with gravity-pressure feed, 22 per cent. with pressure feed and 20.50 per cent. with vacuum feed. These percentages may be compared to British cars, which were found to average 48 per cent. gravity, 28 per cent. vacuum and 24 per cent. pressure fuel feed, and to Continental cars, which showed 50.7 per cent. vacuum, 26.5 per cent. pressure and 22.8 per cent. gravity fuel feed.

TYPES OF ENGINE COOLING.—In 1920 the average American cars showed 2.75 per cent. air cooled, 29.34 per cent. thermo-syphon, 67.85 per cent. circulating pump, as compared to 1915, when 0.50 per cent. were air cooled, 27 per cent. thermo-syphon and 72.50 per cent. pump circulating. These figures can be compared for 1920 to Continental car models, which showed 62.7 per cent. pump and 37.3 per cent. thermo-syphon.

AUTOMOTIVE VEHICLES IN UNITED STATES.—The 1919 registration showed 7,523,664 vehicles registered during that year in the United States, a gain of 23.2 per cent. over the 1918 registration. The 1919 registration showed one car for every 14 persons throughout the United States.

STEERING GEAR

STEERING-GEAR CARE.—There are three generally used types of steering gears, the worm-and-nut, the worm-and-wheel, and the bevel type.

The bevel type requires very little care. The cups, which lubricate the pinion bearing and the steering-arm bearing must be kept filled. They should be attended to at least once every two months. There is generally an adjustment above the piston bearing, with which all lost motion can be taken up.

With the worm-and-wheel type there are generally two adjustments, one which operates on the worm, and tightening of which eliminates up-and-down motion of the worm, and the other in the form of an eccentric bushing, which supports the steering arm and wheel. The first-mentioned adjustment is generally a nut on top of the steering-gear housing. By screwing the nut down the thrust bearings are brought together and up-and-down motion is relieved. The eccentric bushing, which is generally held in adjustment by a locking bolt, permits the wheel to be turned further into the worm, thus giving a closer engagement of the teeth and taking up the lost motion.

One of the chief difficulties in lubricating a steering gear is that there is practically no pumping action. Therefore, a steering-gear housing should be kept very nearly full of grease at all times.

The worm-and-nut type has one adjustment. This a nut on top of the housing, locked with a locking bolt, which puts pressure to the nut by drawing together a slotted portion of the casting. In this type there are two half nuts, which surround the worm. The adjustment removes up-and-down motion at these half nuts. When the adjustment cannot be made with the nut, the worm may be reversed and a new bearing surface will be created. This adjustment is not possible in all makes, however.

For the sector and worm in the steering-gear housing, use a grease or a heavy gear compound.

FLEXIBLE SHAFTING, LUBRICATION OF.—For the lubrication of flexible shafting, such as found on tachometers and other high-speed instruments, an adhesive mineral lubricant, which is a straight petroleum product, free from vegetable or animal oils or other products, and free from fillers, such as talc, resin, tar and all similar materials, the viscosity Saybolt at 212° Fahr., ranging between 1950 to 2200 seconds, is recommended.

To apply the lubricant, remove the shafting from the tubing and immerse it in the lubricant bath, which has been heated to approximately 150° Fahr., or to such a temperature as will cause it to be sufficiently fluid to penetrate between all the bearing surfaces. Then remove the shafting from the lubricant, drain and replace it in the tubing. The tubing should be free from grease or lighter lubricants. The usual trouble experienced with flexible shafting is that it tends to overheat unless properly lubricated.

CLUTCHES

CLUTCHES.—The clutch may be of the cone, disc or plate type. The plate clutch has three plates, two of which are connected to the flywheel. These are called the driving plates. The other is attached to the clutch shaft. This is called the driven plate. The action of this type of clutch depends upon the pressure of the two driving plates against the driven plate.

The cone clutch, which is shown in Fig. 8, Sec. 10d, consists of a pressed-steel cone, which is faced with leather or asbestos. It is made to fit a corresponding cone-shaped recess in the flywheel. Frictional contact is made with the flywheel by means of a compression spring.

Cone clutch

FIG. 8. SEC. 10d.—(Courtesy, *Motor Life*.)

The disc clutch is of two types, the lubricated type and the dry type. The disc clutch is a plate of disc form, a number of discs being used to increase the contact areas. A lubricated type has about 32 driven discs and about 34 driving discs. The dry disc clutch varies only in that there are about six driving discs and five driven discs, and the driving discs are faced with asbestos. The lubricated disc clutch runs in oil. Views of a dry disc clutch and a lubricated disc clutch are shown in Fig. 9, Sec. 10d, and Fig. 10, Sec. 10d.

Disc clutch running in oil

FIG. 9. SEC. 10d.—(Courtesy, *Motor Life*.)

Dry disc clutch

FIG. 10. SEC. 10d.—(Courtesy, *Motor Life*.)

In 1920, taking the average of the American cars, 84.90 per cent. were equipped with the disc type of clutch and 15.10 per cent. with the cone type. This shows a gradual change from 1912, when of the average American car, 44 per cent. were equipped with the disc type of clutch and 52 per cent. with the cone type, the remaining percentages being made up of 3 per cent. expanding-band type and 1 per cent. contracting-band clutch. In 1920, the average Continental cars were 42.5 per cent. equipped with cone, 15.1 with plate clutches, and 0.7 per cent. with band-type clutches, while the British cars were 50.9 per cent. equipped with cone clutches and 49.1 per cent. with disc.—*Automotive Industries.*

TRANSMISSION GEARS

Direct drive

Second speed

First speed

Neutral

Fig. 11. Sec. 10*d*.—Change speed gears. (Courtesy, *Motor Life*.)

TRANSMISSION GEARS.—The speed of an automobile is varied by alternating the engagement of different pairs of gears. These gears are operated on the leverage principle, and the driving gear really "presses" the teeth of the driven gear. Due to the enormous pressure exerted on one or two teeth at any instant, the teeth of these gears must be coated with a pressure-resisting and protecting lubricant.

The change-speed gears, sometimes called transmission gears or gearset, may be of several types. The most common types are the sliding and the planetary.

The sliding-gear type is in most common use. It consists of two parallel shafts, one called the transmission shaft and the other the lay shaft. To obtain three speeds forward and one reverse, four gears of different sizes are carried on the countershaft. There are two sliding gears on the transmission shaft. Views of the gears in several sets are shown in Fig. 11, Sec. 10d. The sliding gears are shifted by forks, which are attached to grooves on the hubs of the sliding gears. These forks are attached to the gear-shift lever.

Fig. 12, Sec. 10d, shows a view of the interior of a transmission. To the left is shown a section of the multiple disc clutch and to the right is shown the sliding gears of the gearset.

The planetary transmission has the different speed gears always in mesh. There are usually only two speeds forward and one reverse. The change-speed gears are revolved on pins that are fixed to the flywheel. When the flywheel revolves, the pins and their

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SECTION No.____

RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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gears also revolve. These gears are meshed with gears on drums, which drums can be held tight by friction bands, at which time the gears on the pins that are moving with the flywheel are not free to revolve, and thus the power is carried to the main drive shaft.

Fig. 13, Sec. 10d, also shows a sectional view of a speed-change gear-set. Fig. 14, Sec. 10d, shows a sectional view of worm driving and differential gears.

Within the cases containing the speed-change gears are the bearings of the main drive shaft, and in the rear-axle housings, cast integral with the differential case, are the bevel gears, or worm gear, and rear-axle bearings. The rear-axle bearings are usually either ball or roller bearings. Due to the fact that the space between the ball or roller bearings and the separator is very small, and due to the fact that their location is inaccessible to some degree, the lubricant used must be fluid enough to find its way to these bearings.

Fig. 12. Sec. 10d.—Cutaway section of transmission, showing disc clutch and sliding gears of gearset. (Courtesy of *Motor Life*.)

When an oil is used, it should be carried at the levels as indicated in the figures. That is in the case of transmission case not high enough to touch the main shaft and in the differential case not high enough to touch the axle. Felt washers should be provided at the points where the shafts project from the cases. These washers should be kept in good condition, as they are put there to prevent the oil from creeping out along the shafts and to stop the entrance of dirt.

TRANSMISSION LUBRICANTS.—Transmission oil should be a straight mineral cylinder stock, with a viscosity of 150–200 at 212° Fahr. (Saybolt).

Transmission lubricants are also made by combining a bright steam cylinder stock with a soap base. By varying the percentage of oil, several consistencies—light, medium and heavy lubricants—are made. A successful lubricant of this type should maintain its consistency through a good temperature range and should not "channel" in the gear-case. An advantage they offer is that they follow the gears better and have less tendency to "creep." They will also withstand a sliding pressure to a greater extent than a straight oil. A lead-base soap is used by some manufacturers, it having the peculiarity of withstanding sliding and wiping pressure, such as met with in worm gears, to a greater extent than the other soap bases.

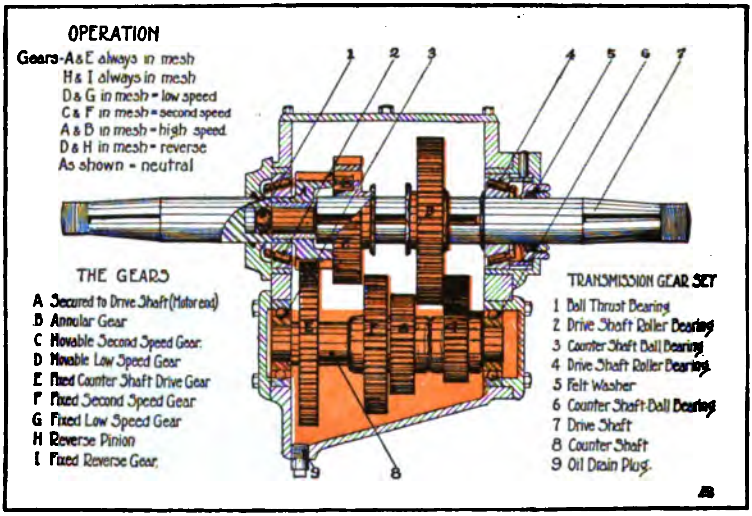

Fig. 13. Sec. 10*d*.—Automobile transmission gears. (Courtesy, Atlantic Refining Co.)

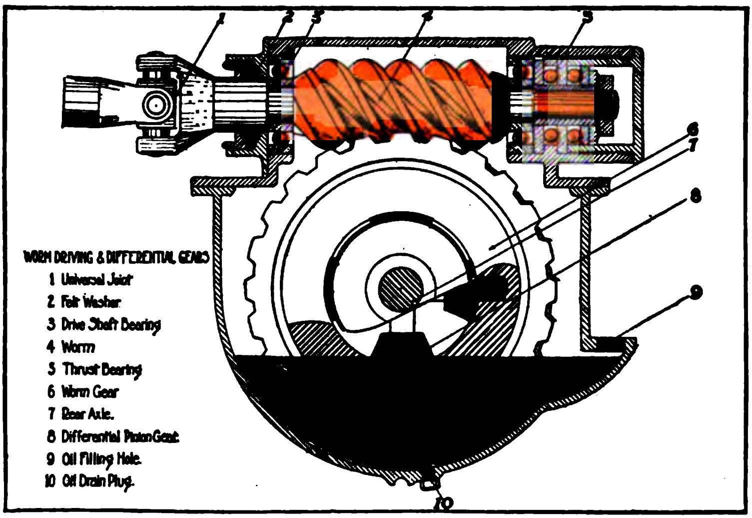

Fig. 14. Sec. 10*d*.—Automobile worm driving and differential gears. (Courtesy, Atlantic Refining Co.)

Transmission lubricants, either oil or manufactured types, should be free from resin, talc, tar, wood fibre and asbestos, and should be neutral. They must possess sufficient body to cushion the gear teeth, and thus relieve the impact of the meshed gears.

COMPOUNDED TRANSMISSION LUBRICANT.—Specification: (Bureau of Aircraft Production, U. S. Army, Specification No. 3505-A; extract from):

GENERAL

1. This specification covers the requirements of the Bureau of Aircraft Production for a mineral-oil compound or grease, which must be suitable in every way for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

PHYSICAL PROPERTIES AND TESTS

2. The lubricant shall be a petroleum compound of calcium, soda or lead soap, and mineral oil, and be manufactured in accordance with the best commercial processes.

3. Manufacturers must at all times maintain a standard consistency in the lubricant conforming to the consistency of the approved sample.

4. Mineral oil base: The mineral oils used in compounding the lubricant, when tested in a Saybolt universal viscosimeter, at 212° Fahr., must show a viscosity of not less than 180 seconds; or, when the character of the finished lubricant is such that the viscosity can be taken in a Saybolt universal viscosimeter, the viscosity of the finished lubricant must be from 70 to 120 seconds at 212° Fahr.

5. Soap base: The lubricant shall have a lime, soda or lead soap base, made from animal fats, vegetable or fish oil.

6. Moisture: The finished lubricant shall contain not more than one and one-half (1 1/2) per cent. of moisture.

7. Acidity: The lubricant must not show more than two (2) per cent. of free fatty acid, and must not attack a sheet of polished copper within a period of 48 hours.

8. Cold test: The lubricant must have a cold test of 10° Fahr. This means that the lubricant must not set firm or channel at a temperature above 10° Fahr. in the transmission or differential gear-case.

9. Moisture test: Fifty grams of the lubricant, with 2 1/2 c.c. of water added, shall be whipped together with an ordinary egg beater, at normal inside temperatures, for a period of 2 minutes. The whipping action shall then be continued and water slowly added until the water content amounts to 25 c.c. Let the mixture stand for 24 hours, at the end of which period and at normal inside temperatures it must not have set or become granular and must not channel.

FILLERS

10. The lubricant shall contain no fillers, such as resin oils, soapstone, wax, talc, powdered mica, graphite, lampblack, sulphur, clay, asbestos, metallic salts, or volatile matter such as naphtha or benzine, or any other substance detrimental to machinery or metallic surfaces.

UNIVERSAL JOINTS.—The lubrication of the universal joint, which is practically an elbow by which a shaft may turn a corner and yet revolve on its own centre, requires special attention. The lubricant is here submitted to a severe rubbing and grinding. Either a fibre grease or a hard cup grease is recommended.

WHEELS.—A semi-fluid oil or a medium grade of fibre grease is recommended for the wheel bearings.

WATER PUMP.—Grease cups for feeding the water-pump bearings and glands work best with graphited grease.

SUSPENSION SPRINGS.—Paint the contact surfaces of the blades with a heavy graphited grease.

MOTORCYCLE ENGINE OIL.—(U. S. Army Specification, Aircraft Production):

This specification covers the motor oil to be used for the lubrication of motorcycle engines.

(*a*) The oil should be a highly refined and filtered mineral oil, or a blend of such oils.

(*b*) It must be suitable in every way for the lubrication of motorcycle engines.

(*c*) The viscosity of the oil must not be less than 110 sec. at 212° F. Saybolt.

(*d*) The carbon residue, as determined by the Conradson method, must not exceed 1.7 per cent.

(*e*) One ounce of the oil must not congeal in a standard four-ounce sample when exposed to temperatures above 50° Fahr.

(*f*) One ounce of the oil, together with one ounce of distilled water, shall be placed in a standard four-ounce sample bottle and heated to a temperature of 180° Fahr., and then shaken vigorously for five minutes. Let stand for one hour, after which the separation of oil and water must be complete, leaving the oil clear and of the same color as before test and the water only slightly cloudy.

AUTOMOBILE SPRINGS.—The noises and squeaks in the springs of automobiles are almost invariably to be located in the spring connections, bolts, or shackles; but not between the leaves. Springs do not squeak between the leaves, but the matter of lubrication of their connections is very important. The connections on the front eye of the front spring are where the squeak most often occurs. For a car weighing about 3800 pounds, with full complement of passengers, the rear springs will be two inches wide, and the diameter of the shackle bolt three-quarters of an inch. This gives a projected area of the bearing of the pin, in the spring eye bushing, of one and one-half square inches. The load on the bolt will vary from 500 to 1500 pounds, depending upon the shocks to which it is subjected, in normal car running. This gives a resultant bearing pressure of from 333 to 1000 pounds per square inch. Due to the variation of the length of the spring, as it is deflected below and above its normal position, the spring shackle oscillates through a small arc around the bolt, with a speed of about three or four feet per minute. This rubbing speed is varied by the rapidity of vibration of the spring, and this in turn depends upon the smoothness of the road surface and the car speed.

In consideration of the above facts, it is evident, that grease is the proper lubricant for spring shackles, as it would not be possible to maintain an oil film under such high bearing pressures and low speeds, particularly in view of the fact, that it is not feasible to continually introduce oil to these parts under the necessarily uniformly high pressure.

LUBRICATING-OIL AND MOTOR-FUEL DATA (CONSUMPTION)

TYPICAL GASOLINE AND OIL CONSUMPTION BY VARIOUS MOTOR VEHICLES.—The following table shows the gasoline and oil consumption, mileage per gallon of gasoline, and quart of oil, for various motor vehicles. The figures were obtained for the month of August. The gasoline used conforms to the Specification G. I. B. of the U. S. Navy. The motor oil used, for motorcycle, was about 85 Saybolt at 212° Fahr., and on motor trucks was about 345 sec. Saybolt at 100° F., with a gravity of about 26.4 B. The figures, in general, show a slight increase for the figures on consumption, over the month of July.

Vehicle	Gasoline (gallons)	Oil (quarts)	Mileage	Consumption	
				Miles per gal. of gas	Miles per quart of oil
54 Motorcycles	1,869	625	43,152	23.08	69.04
13 Kelly-Springfield trucks	976	219	5,559	5.69	23.38
3 Liberty trucks	367	74	1,210	3.29	16.35
1 Packard truck	68	13	409	6.01	31.46
28 Ford trucks (ton)	1,399	346	10,348	7.39	29.90
22 Ford touring cars	1,308	241	16,435	12.56	68.18
3 Dodge touring cars	395	71	5,085	12.87	71.61
3 Ford delivery cars	248	41	3,532	14.24	86.14
7 Cadillac touring cars	1,047	100	10,302	9.83	103.02
1 Napier touring car	131	35	845	6.45	24.14
13 G. M. C. trucks	1,992	393	13,351	6.70	33.97
11 Federal trucks	415	129	2,230	5.37	17.28
15 Standard trucks	572	125	3,358	5.87	26.86
2 Mack trucks	624	114	1,776	2.84	15.57
	11,411	2,526	117,592		

SECTION 10e

BAKING MACHINERY

DOUGH DIVIDERS.—The efficient operation of dough dividers, such as are found in many of the large baking establishments, depends very largely upon the quality of the lubricant used on them and the method of applying it to the machine. The application of the lubricant is usually accomplished by means of automatic lubricators. These lubricators must be so adjusted that there will not be any excessive supply of oil permitted at any time, as the wasted oil will find its way into the dough and cause the bread to have an oily taste.

The lubricants generally used for the lubrication of dough-dividing machines are as follows: Lard oil, cottonseed oil, lard compound, petroleum grease and a highly filtered petroleum lubricating oil, which is known as petrolatum oil.

Lard oil and cottonseed oil have the objectionable features of becoming rancid and gumming the machine bearings. These oils also have an affinity for sugar and will give a bad taste to the bread.

The most approved form of lubricant for dough machines is petrolatum oil. This oil is a highly refined and purified petroleum product, and, due to the fact that it is nearly tasteless, it will not give an objectionable taste to the bread. This oil does not have an affinity for sugar.

A typical petrolatum oil will have the following specifications:

(*a*) Flash-point	390°–410° Fahr.
(*b*) Vis. at 100° Fahr.	130 –140 Say.
(*c*) Cold test	25°– 35° Fahr.
(*d*) Gravity	31.5–33.5 B.
(*e*) Colorless.	

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SECTION 10f

BRICK PLANTS

GENERAL.—There are two problems of lubrication to be solved in any brick plant. The first is the satisfactory lubrication of the dies and the second is the lubrication of the gears and pinion of the "dry pan."

DIE LUBRICATION.—The plastic clay which is to be cut up into bricks or moulded into hollow tile is pressed through a die in the brick machine and comes out in an endless column. While it is transferred to the cutting machine, and comes in turn to the "repress," nothing must be allowed to change the shape of the column or to chip the edges or faces.

To aid the handling of the column it is oiled as it comes from the die. It is again oiled before entering the "cutting machine," to prevent the column from sticking to the steel plate over which it travels, or to the "cutting wires." As the "bricks" come from the cutting machine, more oil is applied, especially to the sides of the fresh clay that have been exposed by the cutting, before they are put into the "repress," where the brand name and the lugs are put on.

Due to the great variety of clays and shales used in brick plants, each operation requires individual consideration. Also the fact of whether brass or steel is used in the cutting machine and repress must be considered, as some oils will prevent the clay from sticking to steel that will not have the same effect with brass.

"Brick oil" or "repress oil" is marketed by many oil companies for the lubrication of the clay columns, as above described. The flash- and the fire-points, as well as the viscosity, is of little importance. The oil must have the following qualities:

(*a*) It must prevent sticking of the clay column to the belt on which it travels or to the cutting machinery.

(*b*) It must be cheap, as the average practice has been found to be about 1/4 gallon of brick oil used per ton of brick made.

Some typical brick oils have the following general analysis:

(*a*)

90 per cent. ....27° paraffin oil.
10 per cent. ....De Gras.

(*b*)

Ordinary torch oil.

"BROCKIE" MIXTURE.—In some sections of the country where Welshmen are employed as brickmakers, a brick oil, known as "brockie" is used for repress work. It is a mixture of about a pint of castor machine oil and a gallon of torch oil. Firebrick was made at these plants.

The following are typical " press oils ":

(a)

5 per cent	De Gras.		
95 per cent	Red neutral	31 Grav.	
		145–150 Vis. at 100.	
		400 Fl.	
		30 C. T.	

(b)

93 per cent	140 Vis. neutral oil.
7 per cent	De Gras.

FIG. 1. SEC. 10f.—Brick column coming from brick machines.

In many plants the brick oils are compounded by the users by mixing cylinder stock or engine oil with an equal amount of kerosene. In some plants a straight red engine oil of about 150° Vis. is used. In others a compound of castor machine oil and kerosene is found to give the best results. In the past, steam and soapy water were largely used for oiling the brick column.

The method of making the bricks and oiling is as follows: Pressure is put onto the clay and it is forced through the die. The oil is fed onto the column just before it enters the die, by means of an oil line and reservoir, which is given a head by suspending the tank at a higher level. Steam or water pressure, preferably water, is used in some plants to increase the head of the oil line. The main reason for putting the oil on the column is to prevent it from sticking to the belt, which carries it to the cutting machine.

When the column comes to the cutting machine it leaves the belt and

must be pushed across the table by the weight of the column behind it. Cloth or sheepskin rollers are used to apply the oil to the top and bottom of the column at this point. After leaving the cutting machine the clay is in the form of bricks. It is then carried on a belt to the repress machine. Here, by means of plungers, the lugs and name are pressed on. The plungers work from both the top and bottom. Before pressing, the fresh-cut sides are oiled again. The bricks are then put into the kiln for drying. In some plants the repress machine is done away with by cutting with the "wire-cut system," which puts on the lugs and the name at the same time.

Fig. 1, Sec. 10f, shows the brick column as it comes from the brick machine. The belt can be seen returning overhead.

FIG. 2. SEC. 10f.—Crown wheel and pinion of grinding pan.

GRINDING-PAN GEAR LUBRICATION.—"Dry pans," as they are called, are used to grind up the shale that is used for making paving bricks. This machine is equipped with a 6- to 8-foot gear, or "crown wheel," and its pinion. The shale dust, which is thickly spread through the air, makes the lubrication of these gears difficult. There is also a step bearing, which carries the weight of the grinding parts, amounting in some cases to 10 to 15 tons. Usually the grinding pans are operated in parts of the plant which are not heated, and low temperatures must be met with for several months of the year. The crown wheel drives two heavy "mullers," which are iron wheels with broad rims, weighing from 10 to 15 tons. Usually the crown wheel is made of cast iron and the pinion of manganese steel or iron. In some plants no attempt is made to lubricate these gears. In others, a lubricant made of cylinder oil and

graphite has been found to give the best results. All of the graphite that can be carried by the oil is used. A mixture of cylinder oil, castor oil and graphite is also recommended for this purpose.

In modern machinery the gears are housed to protect them from the dust.

GRINDING-PAN, STEP-BEARING LUBRICATION.—This bearing is generally housed. It carries the weight of the heavy "mullers." The shale dust works its way into this bearing also and impairs the lubrication. The bearing is generally a part babbitt metal. A heavy black oil, or graphited cylinder oil, will give the best lubricating results.

COST OF BRICK-PLANT LUBRICATION.—Figures obtained from a large paving-brick plant indicate that the cost of the lubricants averages about 2 1/2 cents per ton of brick made.

Fig. 2, Sec. 10f, shows a view of a grinding pan with the crown wheel and pinion.

SPECIAL NOTES.—Formerly clay dust was used in the brick moulds to prevent the clay adhering to them. When brick-making machinery was introduced, oil came into use.

The grade of oil depends to some extent upon the character of the shale or clay used. If the shale is dry and sandy (some shale is 85 per cent. sand), it will require a heavier brick oil, while a shale or clay that is naturally soapy, or of an oily nature, will require a thinner oil.

A pressure of about 20 pounds is usually maintained on the oil. There are grooves usually in the side of the die, through which the shale is forced. The top and bottom of the clay bar requires more oil after passing through the die, before passing through the wire-cutting machine, and it is, therefore, passed between two rolls covered with felt or sheepskin, on which oil is continually dripping, as previously described. Wire-cut bricks have a rough edge, left by the cutter. If a smooth brick is desired, the rough edge of the brick is again run through the oil-soaked rolls and pressed. After coming from the presses the bricks are stored in a kiln and baked.

SECTION 10g
CANDLES

CANDLE MANUFACTURE

GENERAL MANUFACTURE.—In the modern candle works, the paraffin wax is hauled up to the works in tank cars from the refinery. It is then melted and pumped to the melting kettles, which are large copper kettles. Here the necessary amount of stearic acid is added, to give the candle stock of the desired grade.*

When the mix is heated to about 160° Fahr. it is circulated through pipes, which run near to the moulding machines. The stock is drawn off in buckets at the machines, to permit any entrained air to escape, and is then poured from the buckets into the tray of the moulding machine.

A moulding machine consists of a large number of moulds, usually 518, which extend through a water reservoir or jacket. The bottom of each mould is formed of a movable piston; the walls of the mould are stationary. The top of the mould is formed to make a candle tip. The strand of wick extends through the tip and through the hollow piston and the mould. This wick is continuous, and is unspooled automatically as required from the wick bobbins, which are located upon the floor. The melted stock from the trays escapes into the moulds, being prevented from running out by the pistons, which are tight. When sufficient stock has been added so that when cooled there will be a layer of about half an inch above the candle moulds to provide for shrinkage, the stock is shut off.

Cooling water is passed through the water-jacket about the mould sufficiently long to cause the candle stock in the mould to congeal. When the stock has congealed, the surplus wax in the tray is shut off and the candles are ejected by raising all of the pistons at once. The candles are discharged into a rack directly above the moulding tray. They are allowed to remain there until the next batch is moulded, this being necessary in order to hold the wick in position in the mould for the next candle. Before the succeeding batch is moulded the water in the jackets is circulated hot, in order to soften and wash off any wax which may have adhered to the mould. The candles from the racks are then dumped onto shelves, where they are ready for packing.

Fig. 1, Sec. 10g, shows a candle machine, and beside it another machine, which shows the candles raised out of the moulds.

NOTES.—The most satisfactory candle for general use is one composed of 50 per cent. of stearic acid and 50 per cent. paraffin wax. The stearic acid should have a specific gravity of about 0.900 at 48° to 52° Cent.,

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* NOTE. Palm oil is used by many British candle makers for the production of palmitic acid. Composite candles are made from the palmitic acid by hot pressing the distilled palmitic acid. Other materials used in candle making are ozokerite or cerisine, spermaceti and beeswax, the last-named being generally used only for church candles and special candles.

and it should have a melting point of not less than 53° C. It should not contain over 1 per cent. of ash.

A 60-thread wick seems best suited for straight stearic-acid candles, while a 42-thread wick is best suited for a 50-50 candle, as above described.

Candles are known as "fives" or "sixes," according to the number of candles required to weigh 16 ounces. "Fives" candles usually measure from butt to tip 4 3/4 to 4 7/8 inches. With this length of candle, a mixture of 50 per cent. stearic acid and 50 per cent. paraffin wax and 1 1/4

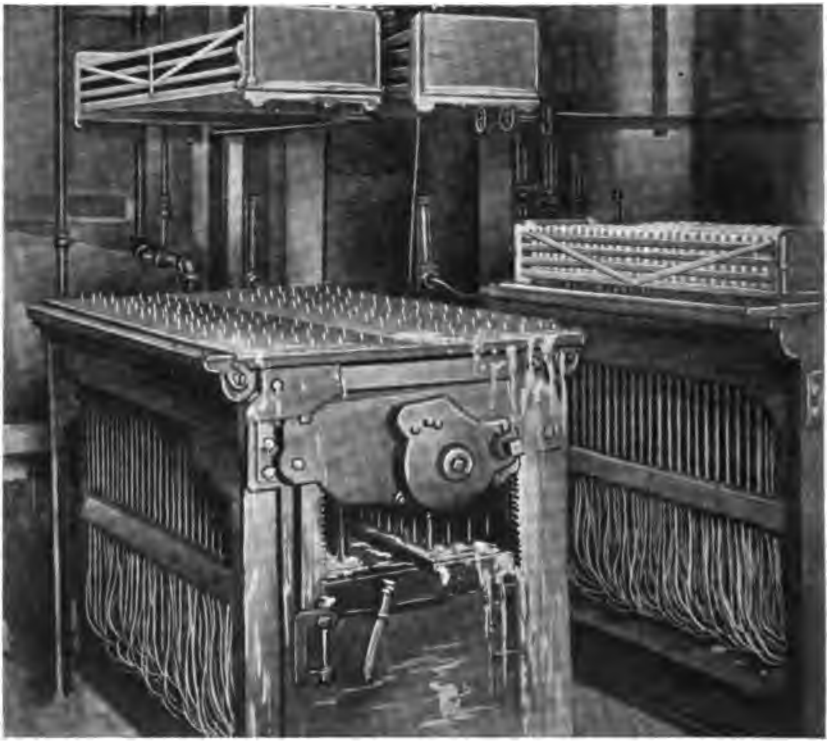

FIG. 1. SEC. 10g.—Candle making machine with wax in moulds and also a machine showing candles withdrawn.

inches in diameter, five candles will weigh 16 ounces. The length of burning time with such a candle as just described will average about eight hours. Paraffin wax will burn longer and give more light, while stearic acid gives hardness and melting-point to the candle.

A "six" candle has a diameter of about 7/8 inch and a length of 8 5/8 inches, and six candles weigh 16 ounces. For this candle, when made of a 50-50 mix, a 36-thread wick is recommended. Some use a 51-thread wick for these candles, but this causes a tendency to smoke. The burning time of this candle will average about seven to eight hours. This style of candle is usually packed in 40-pound cases.

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SECTION 10h

CHAINS AND CABLES

CABLES, WIRE ROPE AND CABLE COATINGS

CABLE LUBRICATION.—Cables should be stored in a thoroughly dry place. If it is necessary to store them in a damp place, they should be well lubricated previously. Cables used in wet shafts of mines must be well protected from the entrance of moisture. In some cases ordinary black oil is used. This oil has little or no value for this purpose, as it does not cling to the surface, penetrate the core nor resist the effects of moisture or other damaging elements.

An efficient wire-rope lubricant must be free from any material that will attack the constituent parts of the rope; it must remain pliable and soft under all atmospheric conditions and must not be subject to evaporation. It must be insoluble in water and should be unaffected by acids, such as are contained in mine water. It must, moreover, have the property of penetration, enabling it to reach every wire and each strand in the core. The failure of wire cables is caused by frictional wear and corrosion of the external elements, and abrasion of the wire and deterioration of the core elements.

Mexican reduced distillate (11° B.) makes a satisfactory coating for wire cables.

If a wire-rope oil is desired, it may be made as follows:

25 per cent. summer black oil.
6 per cent. kidney resin oil.
69 per cent. Mexican reduced distillate (11° B.).

The above lubricant makes a good material for coating the hemp core of a cable, made with a hemp core and steel windings, to be applied during the manufacturing process.

A hoisting rope should be considered as a piece of machinery having many wearing surfaces, which require lubrication. A lubricant that hardens will crack, while bending over the sheaves. Tar should never be used. The rope should be lubricated when dry. Rope may be cleaned by scraping and the use of a wire brush. Some use a special device, which provides a number of compressed-air jets to play on the rope to remove old lubricant and dirt.

CHAIN LUBRICATION.—One of the principal uses of chain transmissions is where a high-speed motor is used to drive a slow-speed machine. Chains are often used to drive automatic stokers.

The lubrication of chain drives is important and should be attended to at least once or twice a week. In some cases where the chain is enclosed, it is possible to have the lower side dip into an oil bath. For a light-running chain, a medium-viscosity machine oil is satisfactory. This oil should be about 240 to 250 Vis. P. B. or 250 Vis. A. B. With this oil graphite should be mixed, in the proportions of three teaspoonfuls per quart of oil. For a heavy-running chain, the oil used should be 275 to 290 Vis. P. B. or 300 Vis. A. B., and should have six teaspoonfuls of flake graphite mixed with each quart of oil.

The oil should be applied to the inner or working side when the chain is running slowly, so that the centrifugal force will not throw the lubricant off. A paintbrush is the best method of applying the oil to the chain. A semi-fluid lubricant of three-eighths the consistency of vaseline is also recommended.

When the chain becomes stiff and dirty, it should be removed and soaked in gasoline, and the dirt blown out by means of an air-blast jet or steam jet.

Where a chain dips or runs through oil at the bottom of its casing, the casing is responsible for automatically lubricating the drive. Chain drives should always be run in dust-tight, oil-tight casings, where dusty conditions, such as cement mills, etc., are met.

Fig. 1, Sec. 10h, shows a casing equipped with an oil pump as designed for a Link-Belt chain drive.

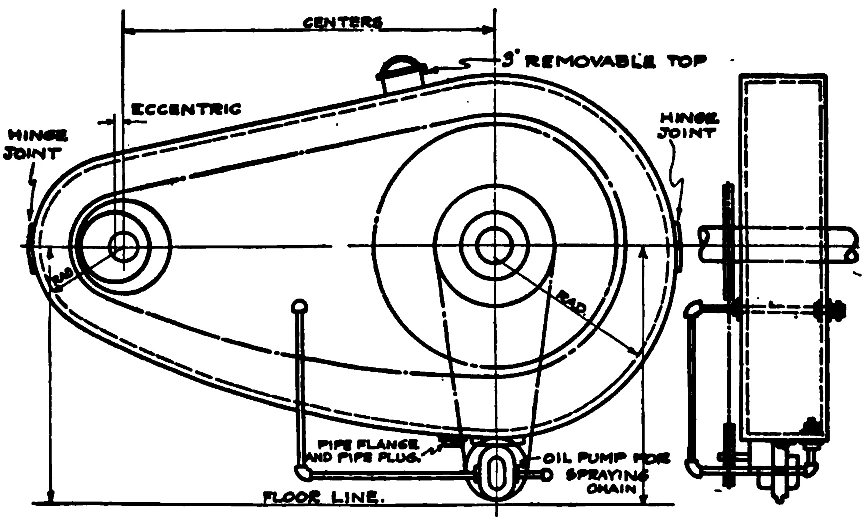

FIG. 1. SEC. 10*h*.—Dust- and oil-tight casing with oil pump for Link-Belt silent chain drive.

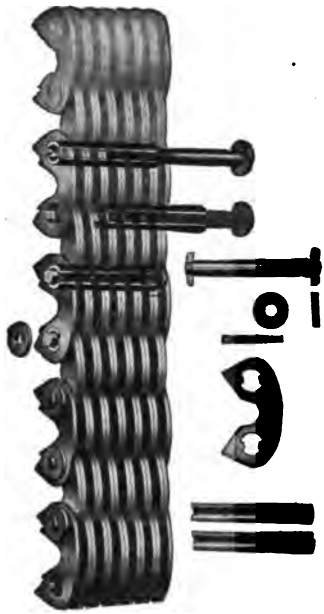

FIG. 2. SEC 10*h*.—The bushed joint of Link-Belt silent chain.

SPECIFICATION FOR WIRE AND HOISTING-CHAIN LUBRICANT.—A lubricant for the lubrication of hoisting chains, wire ropes and gears of cranes, steam shovels, dredges, etc., should be a straight petroleum product, possessing great adhesiveness. It should not contain any vegetable product or any animal products, nor any talc, resin, tar or other thickeners. When it is placed on a sheet of polished steel for a month it should protect the steel from chemical vapors, salt or fresh water, and from the action of water containing 10 per cent. to 25 per cent. of sulphuric acid when the water is at a temperature of 60° Fahr.

It should have a viscosity of about 900 to 1000 Say. at 212° Fahr.

When the lubricant is applied to a wire rope that is clean, it should not crack or peal after it has been exposed to the temperature of the normal atmosphere for 60 days.

A test for penetration of this product is to apply it hot to the outside of a 1-inch wire rope, which is clean, and the lubricant must penetrate and be absorbed by the fibre core, so that at the expiration of a month, the oil will be forced out of the core between the wires, when the rope is placed under strain.

When this product is cut back with 50 per cent. kerosene, it should be liquid enough to be applied with a brush, for swabbing purposes, and as a protection against the weather.

Fig. 2, Sec. 10h, shows the construction of the Link-Belt Silent Chain, as made by the Link Belt Company.

SECTION 10i

CEMENT MILLS

LUBRICATION AND PROCESSES IN CEMENT MILLS.—There are two general methods of cement manufacture—the wet and the dry. In the "dry process," the rock from the quarry is handled by steam shovels and dump cars. It is carried to the crusher, where the rock is crushed by vertical gyratory crushers into pieces about the size of a small potato. The rock is then screened and the fine material delivered by elevators to storage bins. The material left is again crushed and is then mixed with clay or shale. It is then thoroughly dried in large cylinders, which are about 5 to 8 feet in diameter and about 30 to 75 feet in length. They are set at a slight inclination and revolve at about 4 R. P. M. The material moves gradually through these crushers, while powdered coal, or other fuel such as gas or oil, is fed into the lower end and burnt, the heat produced driving off the moisture. The dried material may then be passed through a ball or tube mill. The material is then in a pulverized condition and is transferred to the kiln, where it enters the upper end of an enormous cylinder, which is inclined and is rotated, the combined effect causing the material to pass through the kiln, while pulverized coal, gas or oil fuel is introduced into the lower end and burnt. The clinkers are then removed to rotary cylinders, called coolers. Here they are cooled by air or water and then broken up in ball tube mills and mixed with a little gypsum. The material is then passed through finishing pulverizers and delivered to the point where it is sacked.

In the "wet process" the material is kept very wet and is called "slurry" up to the point where it is delivered to the kilns. Pumps are used to handle the slurry.

The equipment of cement mills consists of steam shovels, crushers, rotary screens, rotary kilns, rotary dryers, tube mills, ball mills, rolls for crushing, elevators and conveying equipment, clinker coolers, and, in mills using the wet process, "slurry pumps."

Lubricating requirements are as follows:

Steam shovels: These machines are operated in all kinds of weather. They are exposed to dust, water, mud, grit, etc. The bearings and journals are liable to excessive wear and the gears to heavy strains, especially those caused by the journals getting out of alignment. For steam-cylinder lubrication, see section referring to that subject in index. For bearing lubrication, see index. For gears, use a pinion grease of the residuum type, which must be tacky and water resisting.

Crushers: Gyratory crushers are a heavy, conical shell, inside of which is a vertical crushing head, carried by a shaft, which is carried at the top by a spider. By means of gearing, or ropes and pulleys and an eccentric, the shaft is given a small circular motion. The gears must be lubricated with a lubricant which will not flake off in cold weather. The lubricant must not be so fluid that it will form a paste with the dust

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

present and cause lumps to form, which will eventually fall off and leave the gears bare. A medium-bodied petroleum-pitch lubricant will meet the demands.

Rotary screens: These screens are used to separate the coarse material from the fine. They are constructed with a girth gear, or may have a bevel gear at one end. There is a large quantity of dust in the air and small pieces of rock. A medium-bodied pinion grease should be used on the gears.

Rotary dryers: These are equipped with a girth gear and a bevel-gear drive from a motor, or line shaft from an engine. The girth gear is kept hot, due to the heat inside. The lubricant used on this gear must be capable of resisting this heat without becoming so thin that it will run off. A heavy-bodied pinion grease is recommended.

Tube mills: These mills are used for grinding, before and after burning. They are used for both the wet and dry grinding processes.

The cylinder of these mills is rotated by means of a girth gear with spur teeth in connection with a spur-gear train. A medium-bodied pinion grease is recommended.

Ball mills or granulators: These consist of a cylinder, which is carried on a large bearing at either end. The cylinder is rotated by a girth gear from a countershaft through a spur gear. Inside are a number of iron balls, which grind the material which is passed into the cylinder through the hollow bearings as the cylinder is rotated. For the bearings, a high-melting-point cup grease is recommended, and for the gears a medium-bodied pinion grease. The bearings run warm. As in all cement machinery, there is a great deal of dust present, which tends to impair the lubrication. The lubrication of "kominuters" is similar to that of ball mills.

Rotary kilns: These are used for burning the pulverized material into cement clinkers. The shell of the kiln becomes very hot, due to the heat produced by the burning fuel within. The kiln has girth gears for rotating it. These girth gears become very hot, and they should be lubricated with a high-melting pinion grease. The combination of dust and heat makes the lubrication of these gears very difficult.

Crushing rolls: These consist of two sets of rolls. One set is driven by a pulley and the other is operated by a fixed roll. There are usually no gears on these rolls, and the many types of pulverizers are seldom gear-driven, being usually directly connected to electric motors or driven by belts or ropes.

Clinker coolers: These are very similar in appearance to kilns. They are used to cool the hot clinkers from the kilns. The girth gears of these coolers do not get as hot as do the gears of the kilns, but the lubricant used must be capable of withstanding fairly high heats without running off. A heavy pinion grease is recommended.

Slurry pumps: These pumps are used in the wet process. They are sometimes equipped with gears for driving, and the best form of lubricant is a pinion grease of medium consistency.

GENERAL LUBRICATING CONDITIONS.—The main trouble to be met with in cement plants is the large amount of dust, which fills the air and covers all exposed parts. The lubricants used on the gears and other parts must serve to protect the rubbing surfaces against cutting

by the rock dust. There are high pressures, which tend to squeeze the lubricant out from the bearing surfaces. In the winter months the lubricants are exposed to very cold temperatures, and the lubricant must function properly at temperatures as low as zero, without becoming brittle and scaling. The gear lubricant must have high adhesiveness and good resistance to thinning down, due to heat. The usual method of applying the lubricant to the girth gears is to heat it and apply it with a brush. In cases where the gears are in continuous operation, a good plan is to thin the lubricant with heat, and to pour it onto the working side of the gear at the point of mesh in a fine stream.

SECTION 10j
CORE BINDERS

CORE MAKING AND FOUNDRY PRACTICE

IRON.—When iron is in a molten state it is a liquid, and behaves similarly to a liquid in all respects, therefore, when the iron is confined in a mould, the conditions of liquid pressure exist.

In order to confine the iron, so that it may be poured in this liquid state, into a mould of predetermined shape, so that when the iron cools and becomes solid it will take that shape, sand is used to make the mould. The sand itself is confined in a container, called a "flask."

Cast iron is not a pure metal, but contains about 93 per cent. to 94 per cent. of the pure metal, and the remaining 6 per cent. to 7 per cent. consists of carbon, silicon, phosphorus, sulphur or manganese. Occasionally there are also present percentages of arsenic, titanium and chromium.

MOULDING.—Sand is used to form the mould for casting the metal. Sand possesses the required characteristics, making it suitable for this purpose, which are: (*a*) Plasticity, to permit of its being moulded into a form corresponding to that which it is desired for the metal to take; (*b*) Porosity, which is necessary to permit the escape from the moulds, of the air and gases, that may be generated when the hot metal is cast; (*c*) Firmness, to give it body to hold its moulded shape against the liquid pressure of the molten metal; (*d*) Heat resisting, so that it will not disintegrate in the presence of excessive heat and the chemical action of the hot metal. (In some cases iron moulds may be used; this process being known as "chilling.")

In order to give to the sand the desired impression or mould, "patterns," usually made of wood, and having shapes which are practically counterparts of the shapes of the castings wanted, are used. When castings which have hollow portions are to be made, they are produced with the aid of a "core." In order to support these cores in their proper location in the mould, projections, called "prints," are provided on the patterns, and these "prints" leave recesses in the mould after the pattern has been withdrawn. The cores are set into these recesses.

The moulding box, in which the sand is confined, is called a "flask." The lower portion of a mould may be in the sand of the floor and the upper portion may be in a flask, or the flask may be split in the middle, so as to facilitate the removal of the pattern after the mould has been prepared, in which case the entire mould is in the flask. The upper part of the flask is then called the "cope" and the lower part is called the "drag." Sometimes the flask is split twice, in which case the middle section is called the "middle."

When the pattern is to be removed from the flask after the sand has been moulded, a process known as "rapping" is carried out. In order not to injure the mould when the pattern is withdrawn, the pattern is given a "taper" or "draught," which means that the lower portions of the pattern have slightly smaller dimensions.

When metal cools it shrinks, and allowance must, therefore, be made for this contraction by making the mould correspondingly larger.

CORES

CORES.—The term "core" is self-explanatory. Any central portion removed from a body is a core. Cores are used when there would be great difficulty in constructing a pattern of such a form that impressions could be taken of the central portions, or when the cutting out of the internal portions of the patterns would cause them to be weak, or where it would be difficult to put the mould together and "vent it" without the use of the cores.

The substance of cores must usually (but not always) be stiffened with rods, grids or nails. "Vents" of sufficient area to carry off the gases must be provided when necessary.

When the "core box" is received, especially if it is an intricate one, it is first examined by the "core maker," to plan for the vent wires or rods. If it is a large core, reinforcing rods must be used, and they must be located in such a manner that they can be removed after the casting has been poured. Sometimes a cast-iron "spider" is made, so that it can be easily broken after the core sand has been "broken out."

SAND

SAND.—"Green sand" refers to sand in its natural state; that is, just damp enough to render it cohesive. After the pattern has been removed, the mould is cleaned up, "mended" and then "blackened," when it is ready to receive the metal.

"Facing sand" is that which is rammed close around the pattern. Different mixtures for facing are used for green sand, dry sand or loam. Facing sand is used, because otherwise the molten metal would slightly fuse with the surface of the sand in the mould, giving a rough casting. Coal dust may be used in the mixture for facing sand for some kinds of moulds.

"Burnt sand," or "old sand," or "débris," refers to sand after the carbon of the coal dust has been oxidized, at casting. The best part of it is mixed with new sand and coal dust, to be used for facing sand, or it may be thrown onto the floor, to be used only for box filling, where the sand does not come near the pattern. Burnt sand, or débris, is sometimes used to make cores. However, since the sharp corners and edges of the sand particles have been fused off, débris has poor binding properties.

"Parting sand" is a loose, open sand, used without moisture to prevent sticking at the joint surfaces.

For mixing the sands in the foundry, various equipment is used, such as sifters, riddles, loam mills, etc.

CORE SAND.—The principal heat-resisting element in core sand is silica. Moulding sand usually does not contain over 80 per cent. of silica, and the rest is made up of alumina, oxide of iron, etc. Some clay is required in moulding sand to give bond. Sharp sands for oil mixtures contain about 97 per cent. of silica and are bondless, while bonded sands contain as low as 90 per cent. silica.

Various kinds of sands are used for core making. The character of the work usually decides this question. The sands used run from clean-washed silica to what is known as "Jersey gravel." The different formulas for percentages of mixtures with core binders are as numerous as there are foundries.

It is necessary that a core be free venting, and it, therefore, follows that the sand used permit of a sufficient number of voids to permit this venting. Furthermore, the sand must be bound together, so as to give strength, and these bonds should exist at the contact points, so that spaces will be left between the sand grains for venting.

The strongest cores made from oil-sand mixtures are those in which the sand grains are slightly rounded, since there will be larger areas for contact points and a good area for venting. The greatest number of fine venting voids are desirable. They must be fine enough, however, to permit of no tendency of the metal flowing in between them. This requires that different sands be used according to the kind of metal to be cast. Brass and bronze have the characteristic of being penetrating into cores that would not be affected by iron. The brass and bronze metals have lower melting-points, and, therefore, remain fluid longer than iron when in contact with the core. Also iron, when fluid, seems to be more viscous than brass or bronze when they are fluid. Aluminum has the same characteristics as iron. If brass or bronze contains phosphorus,

it is particularly penetrative. Phosphorus also increases the penetrative action of iron.

It is essential that, according to the kind of work, cores must possess a sufficient strength per square inch, and must disintegrate enough to allow the metal to shrink when cooling.

Core sands that are to be used with oil as a binder, should be free from shale and limestone pebbles. The shale is apt to give a fluxing effect. Sands which contain a considerable percentage of limestone pebbles should be used with glutrin or black-pitch binders.

Core sand should be dried before measured for making a core mix, so that the weight of the moisture in the sand will not throw the relative proportions of the binder and sand off.

It is very important that the sand and binder be thoroughly mixed, so as to insure every sand grain being coated with the binder.

The grains of sand should be as uniform as possible, to insure the core having a maximum venting space.

ACTION OF METAL UPON THE CORE.—Fig. 1, Sec. 10j, shows a cylindrical core in a mould and the molten metal filling the mould. The metal comes in through a gate, as shown, and, of course, flows to the bottom of the mould. Before pouring starts, the mould is full of air. When the hot metal begins to enter, this air is heated, and consequently expanded, so that the volume of air to be expelled by the metal is increased over the amount of volume of the mould. Some steam is also created. This steam and air escapes through the mould and the core, as shown, but, as the mould fills, if the metal is at the right temperature, a metal film or skin forms on the mould and the core sides, as shown in the figure. This skin stops the passage of the gases from the core and mould into the metal and from the metal into the sand. If gas is generated in the mould faster than it can be carried off by the vent, then a "blow

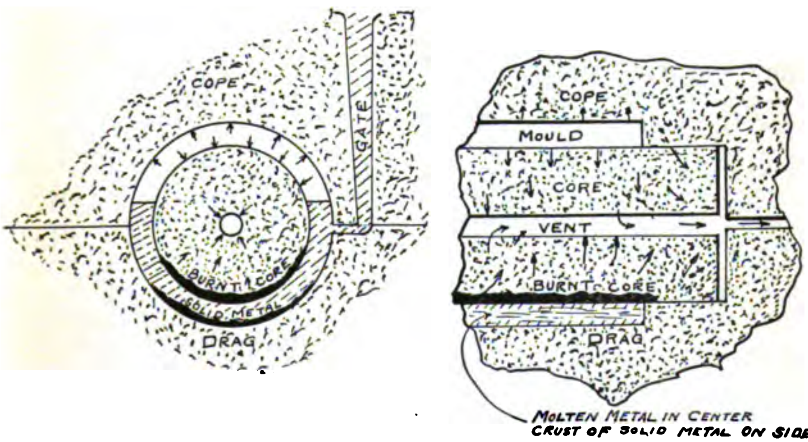

FIG. 1. SEC. 10*j*.—Illustrating action of metal on core.

back" will occur, and "scabbing" of the casting will result. As the core surface is covered by the metal, the hydrocarbon compounds forming the core binder are driven off, and should be forced into the vent or pass through the core.

The volume of gas which will be generated during the pouring of metal around a core is proportional to the volume of hydrocarbons which can be distilled from the core binder. At first, these gases may contain carbon monoxide while there is air in the mould and core to supply the necessary oxygen. Then, when this air is exhausted, the gases which will be driven off are only those driven off by heat. Since the core is dry, there is no steam. It is, therefore, evident, that the ideal binder will be one which contains just sufficient hydrocarbons to give a strong core without producing, while pouring is in process, excessive gases. The baking temperature of the core is a factor, since some binders can be baked at a sufficiently high temperature to insure the gasification of the great percentage of the volatile hydrocarbons, with the result that there

is left in the core to act as a binder practically solid carbon. However, this condition is not practical, as there would then be a tendency to form cracks in the core, due to the great reduction in volume of the core binder, and an excess of binder would be required in order to obtain the desired strength. Furthermore, as the hydrocarbons are driven off by the hot metal, the heat should be conducted slowly enough through the core material so that there will be a slow enough distillation to permit the gases generated to be handled, and to also keep sufficient binding power in the core to hold it together until the skin, which is forming on the outside, will be strong enough to resist the cutting action of the metal on the core surfaces. In some cases, the binder must contain an excess of fixed or free carbon, since this tends to reduce the cutting action of the metal, which explains why it is necessary in some cases to use an excess of core binder.

CORE BINDERS

ESSENTIAL CORE-BINDER REQUIREMENTS.—There are several essential properties that should be possessed by an efficient core binder, namely:

(*a*) Right from the time the core is made until it is used, whether that be the same day or sometime later, the core must keep hard and retain its sharp edge. It must withstand severe handling.

(*b*) After the mixture of sand and binder has been made, it must stay wet and mouldable, sometimes for many hours, until used, so that cores can be made up, even the next day, without remixing.

(*c*) After the core has been made, it must be waterproof and must not pick up moisture, either from lying in the core room or from the paste, if pasted cores are made.

(*d*) The core must come out of the box clean, and must leave no residue behind for the operators to wipe out. This would mean a loss of considerable time. Linseed oil often causes trouble from sticking, due to gumming.

(*e*) The core must "break back" into free-running sand easily, after the casting has been made. It should flow out easily "after the pour," at the first "knock," with no lumps or residue to stick to the metal.

(*f*) After the core has been moulded in the core box, it is put into an oven, called a "core oven," where it is baked. Quick baking is an important property and the core should bake right through to the centre.

(*g*) A good core binder will show a minimum of smoke when the core is baked. This is important, especially in winter, when the windows are closed.

(*h*) The core should be porous and free venting, and at the same time the metal must "lie close." With a good binder, there will be no blowing, if the core is right.

(*i*) The core must not "cut." A good binder must not lose strength in baking, and must stand up when the metal flows around it.

(*j*) Absolute uniformity is essential, as the cores must be made to one standard.

TYPES OF BINDERS

TYPES OF CORE BINDERS.—The two main types of core binders can be generally classed into the dry or plastic paste form and the liquid form.

Binders, which come under the first, or plastic form, do not act in the same manner as those of the liquid form, since they do not flow to the contact points of the sand grains, when they are baked.

In the case of a liquid, or oil binder, the sand, tempered with water, is first thoroughly mixed with the desired percentage of oil, so that every grain is covered. The core is then placed in the core oven and baked, when the moisture is driven off and passes through the core to the outside surface, where it is driven off as steam. The oil, having more body or viscosity than the water, remains behind, coating each grain of sand. Then, by the action of capillary laws, the oil on each grain draws to the contact points of the grains, at which points, as the drying progresses, the oil dries and forms a bond, binding the grains—the area of bond depending upon the body of the oil.

On the other hand, such binders as flour or dextrin, do not flow to the contact points, but dry where they are on the surface of the sand grains. Thus only the relatively small amounts of binder occurring at the contact points of the sand grains become efficient as binder, while the material existing on the surface of the grains merely tends to reduce the venting action by filling up the voids.

Black compounds or pitch binders are only suitable for heavy work, since there is no requirement here for the high strength, as met with in smaller cores.

Some foundries use such products as sour beer, distillery slop, etc., but these are not satisfactory, due to their poor binder qualities.

Molasses is also used, but its main objection is its non-uniformity. This is due to fermentation and to the variation in binding power, due to the different sources of production.

In recent years there has been a great reduction in the cost, time required and necessary skill for making cores, through the use of sharp sand and oil binders, in place of the old type of core sand, with flour and other binders.

Oil-sand cores require little or no ramming and can be made by unskilled labor. In some cases, core costs have been reduced through the use of oil-sand cores by as much as 50 per cent., while at the same time fewer "wasters" and "blow outs" have resulted. No venting and few rods are required.

CORE OILS.—The best-known liquid binder for cores is said to be pure linseed oil. Owing to the high price of this oil, it is the general practice to substitute for it a product composed of part linseed oil and the remainder consisting of a cheaper vegetable oil, a mineral oil, and in some oils a resin or fish oil. Usually a neutral mineral oil is also used, the percentage running about 10 per cent. to 15 per cent. The mineral oil reduces the cost of the oil and also aids in preventing the sand from sticking to the "core box," in which the core is made.

Some of the oils used for core-oil, blending or straight, are: Linseed, soya-bean, fish, corn, mineral, cottonseed, tar oil, resin oil, china-wood, etc.

Raw linseed is slow drying, but is one of the strongest binders. Boiled linseed oil is a quicker dryer but does not have the binding powers of raw linseed. (See fatty-oil section for data on these oils.) Since the preparation of boiled oil hastens its "setting," or drying, properties, by partially oxidizing it, this explains its lower binding value.

China-wood oil (see index) dries readily and has the general characteristics of a natural varnish. It gives good results as a binding element.

Light tar oil, when dried down to a hard film, loses about 89 per cent. of its weight. It is used in blending some core oils.

Resin oils are usually found in blended core oils. Neutral mineral oil is also used, but has little or no binding value, being of use only to aid waterproofing, in the removal of core by preventing sticking to the box, and to carry the resin into the mixture.

The important bonding elements in a core-oil blend are the drying oils, and they require a good circulation of air in the core oven when baking. In case tar oil or mineral oil is used, some volatile hydrocarbons will be driven off, and a good circulation of air is necessary in the oven to produce oxidation of the oils.

By reference to the section on tests of fatty oils, it will be seen that, in general, the oils mentioned as used in blending core oils have flash tests above 500° Fahr., and for this reason the core oven may be kept at a higher temperature, when this type of binder is used, than is the case with flour or dextrin, etc. In general, the temperature of the ovens should run at about 405° Fahr., and if the temperatures should be run up to as high as 575° to 600° Fahr., it will be found that in most cases the cores will be weak.

Linseed-oil foots is used as a core binder in some cases, and seems to have good binding powers, but will stick to the boxes.

See index for linseed foots. Also see index for reference to drying tests on various oils.

Fish. and whale oils are good binders, but give off very disagreeable odors.

BINDERS OTHER THAN OIL.—The action of resin or pitch in bonding sand for cores is effected by their melting and flowing over and between the sand grains. They collect to some extent at the contact points, as the core cools. These binders do not combine with clay, but add their binding power to that possessed by the clay, and when the hot metal is poured over the core, the carbon material of the pitch or resin is burnt and the core disintegrates, so that it can be easily knocked out of the casting.

Flour and dextrin are used as core binders, but tend to stop the venting, due to the fact that they do not flow to the contact points, but dry on the surfaces of the sand grains. Only that part of the binder which occurs at the contact points is efficient.

Molasses is used for some cores. The molasses on the sand grains tends to "boil up" when put in the oven, and then hardens in thin films at the contact points. If cores made with this binder are left too long in the oven, they will be weakened, due to the oxidization of the carbon. The sensitiveness of this binder makes it difficult to obtain uniform cores.

GLUTRIN.—This is a by-product of a sulphite paper mill. It has great affinity for moisture, and this tendency is objectionable in connection with its use as a core binder, as it makes it impracticable to stock cores made with it, as the dampness in the atmosphere will soften them in a short time, making them unfit for use. If these cores are left in the mould overnight or over Sunday, they will soften and break down. These references are to cores which are made entirely with glutrin. Glutrin mixed with core oils will improve their binding qualities, while the oil waterproofs the core.

The best practice in foundries is to make one or two forms of cores, until a considerable stock is on hand, and then to repeat this process with other forms. Therefore, the stocking factor is important, and care must be taken to use a binder which will resist moisture. Results that are satisfactory have been obtained by mixing 50 per cent. of glutrin and 50 per cent. of a good core oil as a binder. The core oil moisture-proofs the cores and makes them capable of being stocked for a long time. They will also stand handling much better without breakage.

Glutrin is soluble in water. Its composition is complex and it may contain tannins, wood sugars and resin in a soluble form. These do not combine with clay, but form with it an emulsion, which tends to carry it from the sand-grain surfaces to the contact points.

In the case of sand, free from clay bond, the glutrin tends to follow the moisture to the surface of the core, giving a hard skin and a soft inside.

Glutrin, used in connection with oil, will form an efficient bond, since the sweating feature of the glutrin will be overcome by the action of the oil.

A sample of glutrin heated in a current of air, in a porcelain crucible, lost 48 per cent. of its weight after 24 hours' heating at 212° Fahr., and on further heating at 400° Fahr. in a core oven the sample was reduced to 42 per cent. of its former weight. When heated to dryness in the air, there was a skin formed in the crucible, amounting to 7.8 per cent. of the former weight of the sample. The sample dried down to a film similar to that formed by oils, and the cores formed with it retained their size, no swelling occurring.

FORM 1 HP

SECTION No.

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

USE OF CORE OIL

METHOD OF USING CORE OIL.—Oil is mixed with the sand, to serve as a binder, so that when the core is subjected to heat it will cement the sand together. Thus an accurate core is obtained. Fig. 2, Sec. 10j, shows a core box for making round cores.

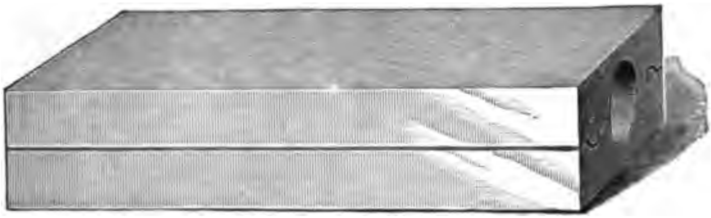

FIG. 2. SEC. 10*j*.—Wooden core box, round cores.

FIG. 3. SEC. 10*j*.—Portable core oven.

In some industries the cores must be very accurate. For instance, in casting an automobile engine "*en bloc*," the cylinder walls may be only 5/32-inch thick.

The sand used for oil cores should be free from anything of a loamy or earthy character. The proportions, in general use for the mix, are from 1 to 20 to as high as 1 to 90, the higher number being the sand. The mix can be worked in by hand or a mixing machine may be used.

After the core has been shaped in the core box, it is baked in an oven. Fig. 3, Sec. 10j, shows a portable core oven. These ovens may use as fuel: coke, gas, oil or coal. It is here subjected to a high enough temperature to cause each particle of sand to become coated with a crystallized

FIG. 4. SEC. 10*j*.—Core room train-rail loaded with cores.

oil film. When baked, a core should be produced that is dry, hard and not easily chipped. The temperature to which the core is subjected in the oven may vary from 375° to 550° F.

The proportions of sand and oil must be varied according to the kind of work, grade of sand and kind of core.

CORE-ROOM EQUIPMENT.—Fig. 4, Sec. 10j, shows a tram rail, which is used in large core rooms for handling great numbers of cores. The figure shows a number of cores of different shapes being loaded.

Fig. 5, Sec. 10j, shows a core-making machine, hammer type, which is used for making round-stock cores; also square, hexagonal, oval, rectangular cores and slabs. The cores are vented by a pin, which is machined in each screw. Core trays are provided with the machine.

CORE-ROOM PRACTICE.—There are probably more difficulties in the "core room" of a foundry than in any other department, caused by the uncertainty of mixing the sand with flour, resin, molasses, oil, sawdust, etc., in the correct proportions, to make the cores have the correct hardness and at the same time "rap" out easily. This can only be overcome by studying the requirements of the cores, and obtaining the correct combination of core sand and core oil or binder. There are some forms of core binders on the market which are called dry binders. These binders

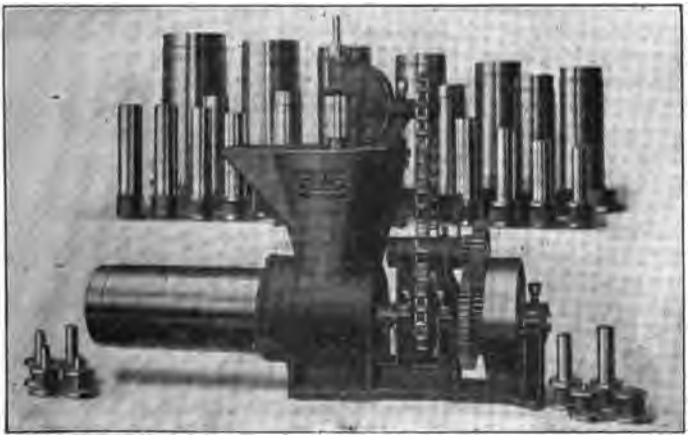

FIG. 5. SEC. 10j.—Core machine, hammer type.

usually have a glutinous content, so that when the core is placed in the oven to dry, the heat is sufficient to soften this glutinous substance and glaze the core. These forms of binders are sometimes used on such work as loam work, cylinders, bed-plates, heavy machinery, pipes, columns, car wheels, agricultural work, radiators, waterbacks, etc. The sand is usually damped with molasses water and then the dry binder is mixed in.

Oil can be successfully used for many of the above operations, if the conditions are properly adapted.

Many brass foundries use flour as a binder. It is also used for making paste. In some foundries, using dry binders or compounds with heavy work, sawdust is mixed with the sand to aid in venting the core.

When core-making machines are used, it is necessary to use oil as a binder with the sand mixture. It lubricates the screws and tubes and prevents making a core that is too hard.

CORE MIXING.—A small quantity of clay in the sand will affect the strength of oil-sand cores. Clay absorbs the oil and prevents it acting as a binder. The clay that affects the oil is the colloidal form of clay.

Sands from local banks usually vary greatly as to their value in forming oil-sand cores. This is due to the fact that rains may wash the surface soil, or clay, into the bank. This destroys the binding power of the sand as regards oil binders.

Clay has the opposite effect upon the binding power of a product such as "glutrin," which is a wood-pulp product, as it increases the binding power of this material.

Clay has little effect upon such binders as flour, starch, dextrin, etc., except that clay will clog up the vent passages.

One of the most important factors, in connection with core making, is the proper mixing of the sand and the binder. An even distribution of the binder in the sand is absolutely necessary. In some cases the amount of binder used has been decreased 40 per cent. by better mixing.

Dry and warm storage should be provided for cores, and they should not be exposed to undue moisture. Care taken in this connection will very often result in decreased amounts of binder being required to do the same amount of work.

In connection with mixing the sand for use in core-making machines, the manufacturers recommend that only dry sand be used, and with this, foundry flour is mixed and linseed oil or a manufactured core oil. If the cores are small, no water is necessary; the larger the cores, the more water the mixture will take.

As an illustration of formula for use with core machines, the following, (*b*), (*c*) and (*d*), are those given by the manufacturers of a well-known core machine. They may not work successfully with all grades of sand. However, they give a general line to work out individual formulas from. For the linseed oil in the formulas, a high-grade manufactured core oil can be substituted.

(*a*) *For gray-iron cores use:*

1 part foundry linseed oil or core oil.
10 parts flour.
50 parts clean-washed silica, beach, or fine, sharp sand

(*b*) *For brass and aluminum castings:*

4 quarts silica or good sharp sand.
2 quarts brass-moulding sand.
1/4 pint boiled linseed or core oil.

(*c*) *For steel castings.* (The melting point of steel is about 500° F. higher than that of gray iron.) This mixture is used without grinding.

6 quarts silica sand.
1 quart flour.
1/4 pint boiled linseed oil or core oil.

(*d*) *For steel castings, cores 2 1/2 inches and above:*

18 quarts silica sand.
3 quarts fire clay.
1 1/4 quarts flour.
1/2 pint boiled linseed.

NOTE. The steel mixtures must be very thoroughly mixed. The fire clay can be increased or decreased, according to the hardness of the core, with the sand being used. The above core mixtures are in use in a number of foundries.

CORE TESTING

TESTING CORE BINDERS AND OILS.—The selection of the best sand and the most efficient and economical core binder is a matter of the utmost importance to the foundryman. Many attempts have been made to control sands and binders by chemical analysis. This method is in no way as successful, as is practical testing.

The regular cement testing machines are not sensitive enough to get accurate comparative data for these tests.

Fig. 6, Sec. 10j, shows a crude method used by many foundries for testing the strength of cores. The core is made in the box shown in Fig. 7, Sec. 10j, which gives a core 1 inch in cross section and 15 inches in length. This core after baking is supported as shown, allowing 1 1/2 inches on either end for support. The bucket and supporting wire is hung

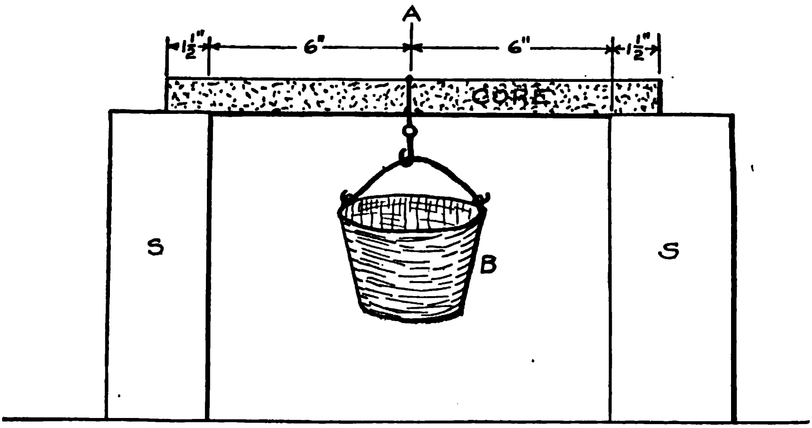

FIG. 6. SEC. 10j.—Rough method of testing core binder strength.

on the core as shown, shot is dropped into the bucket until the core breaks, when the bucket, wire and shot are weighed, this giving the total weight that is required to break the core. Care must be taken in making this test to be sure that the shot is added at a constant and uniform rate. This method of testing gives fairly satisfactory results for testing oil-sand cores, but is not sensitive enough for cores with low breaking strength. The tensile method of testing is preferred to this method, but it serves to give a demonstration test in the average foundry. In cases where the binding power is low, the length of the bar should be decreased to about 6 inches of span. In comparing the binding values of two core binders, two cores are made, using the same sand and moulded in the same core box. The two cores are then baked on the same plate and under the same conditions.

The breaking operation, as described above, is repeated for both cores, and the relative strengths of the two core binders is thus demonstrated. The next step is to make up cores with different percentages of

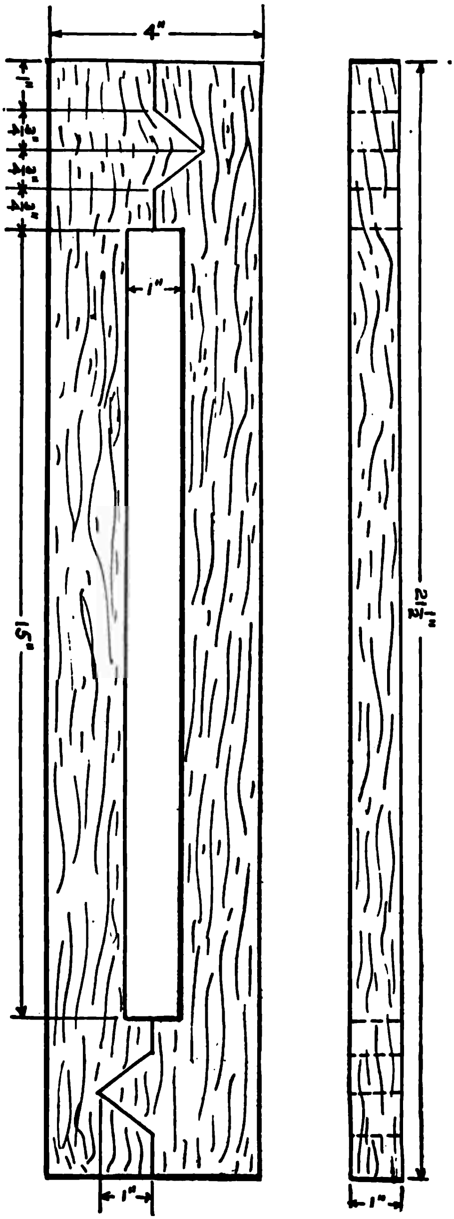

FIG. 7. SEC. 10*j*.—Core box for making test core.

the two core binders and to then compare their breaking strengths for the different mixes. The result should be tabulated, together with other information, as to the general appearance of the cores, their porosity, hardness at the corners, etc. (Usually tested for hardness by running the finger-nail along a sharp corner.) The porosity is demonstrated sometimes by blowing smoke through the core.

Rough tests can be secured by making the cores in cement briquet moulds and baking them as above described, and then pulling them in cement testing machines, but, as above stated, it is not possible to obtain very accurate results by this method.

The test cores are usually baked in the regular foundry core oven, but a more constant temperature and uniform set of conditions can be secured if a laboratory core oven is used. Under ordinary conditions, a single plate of the cores is baked at a time, the plate being placed on the top shelf, so as to bring it near to the bulb of the thermometer. Ordinary oven thermometers are not accurate enough, and a high-grade mercury thermometer should be used. The thermometer is passed through a small opening in the top of the oven during the baking.

In making test cores to compare sands, care must be taken to use dry sand, for it has been found that from 8 per cent. to 10 per cent. of moisture, by weight, in sand, may increase its volume as much as 40 per cent. when it is not packed hard in the measure. No sand should be packed when it is being measured, as the force exerted upon the sand when packing it would have a distinct effect upon the amount of sand placed in the measure. For comparing sands, a standard core oil should be kept for this purpose.

MACHINE TESTING

CORE-TESTING MACHINE.—Fig. 8, Sec. 10j, shows a machine made by the Wadsworth Core Machine and Equipment Co. The machine as now constructed, uses a core made in the form of a briquet, generally employed in the testing of cement and concrete. The machine shown in the figure has a leverage system proportioned in the ratio of 1 to 3. The mixture to be tested is made into cores in the core box shown in the figure. The cores are then baked at a *standard temperature,* which has been previously decided upon, and when finished, are placed in the grips, shown at the left of the machine. The hopper, back of the machine, is filled with shot, and a small pin, which works in a slotted link above the bucket, controls the valve at the bottom of the shot hopper. After the core is in place, the bucket is hung on the hook and the pin con-

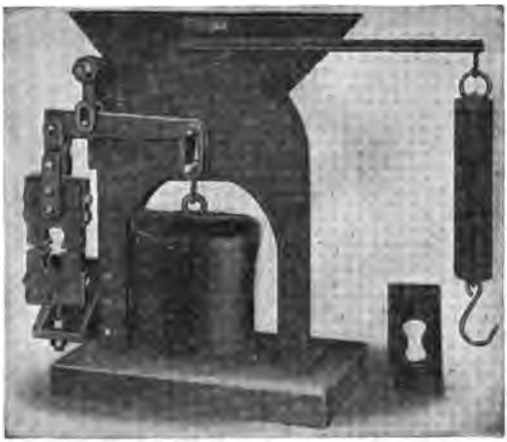

FIG. 8. SEC. 10*j*.—The Wadsworth core testing machine.

trolling the valve is raised. The shot then start to flow into the bucket, and the minute the core breaks the bucket drops, when the slotted link throws the control pin and shuts off the shot supply. The shot are then weighed on the scales, shown to the right. When standard scales are used, the weight indicated must be multiplied by three (3) to obtain the true weight that broke the core.

The manufacturers state that for oil-sand mixtures and other similar strong cores the system of levers is necessary, as otherwise the amount of shot required to break the core is too great to be conveniently handled. When very weak mixtures are tested, an extra pair of jaws is provided, giving a direct pull.

Fig. 9, Sec. 10j, shows a Riehle machine for testing cores, made by Riehle Bros. Testing Machine Co., and the following directions apply to its use:

First, a briquet is made from the sand in a standard cement mould as

recommended by the A. S. T. M. After baking, the briquet is placed in the grips of machine, and the load is applied by a hand wheel at as near a uniform rate of speed as possible. Before making the test, the wedge is placed in the position shown in the illustration, and when the load is

FIG. 9. SEC. 10j.—Riehle Bros. core testing machine.

applied on the briquet, the pointer on the dial moves and the wedge slides downward, holding the recoil lever in place, thus taking the recoil off the springs of the balance and holding the pointer at the breaking point. After the specimen is broken, pull down the recoil lever and release the wedge, and the pointer returns to zero.

CORE-OVEN NOTES

DRAWER-TYPE CORE OVEN.—Fig. 10, Sec. 10j, shows a view of a drawer type of core oven, as manufactured by the W. W. Sly Manufacturing Co. A number of cores are shown on the plate, as they are about to be pushed into the oven for baking.

CORE-OVEN TEMPERATURES.—In foundries where the cores are baked overnight, unless an especially good man is in charge, the ovens will probably cool off about 2 A.M., and then, in order to make up the lost

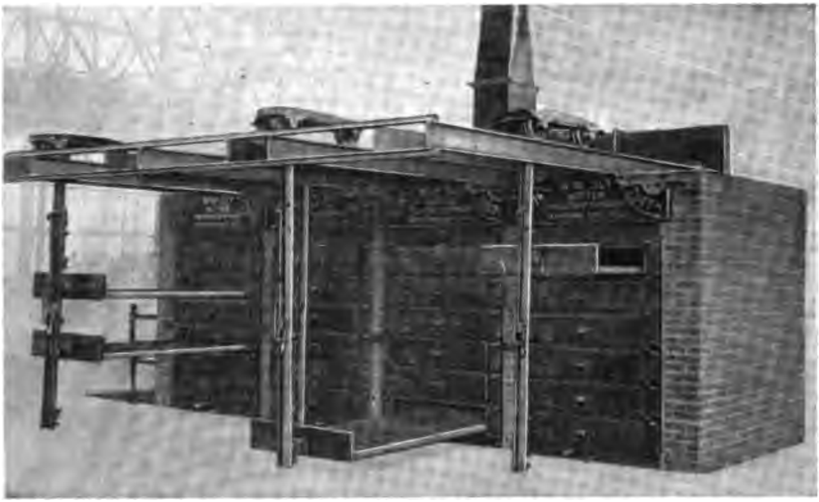

FIG. 10. SEC. 10j.—Drawer type of core oven, showing one drawer pulled out.

heat, they will be forced during the next few hours. As a result, the cores, that are turned out after this forcing, are dried hard on the outside, but are soft and moist in the centre. When the hot metal is poured, the moisture forms gas, which escapes through the porous shell of the core and causes blowholes in the casting.

In adjusting complaints regarding core oil, the evenness of the oven temperatures should be taken into consideration. In the most modern foundries, a long-distance recording thermometer is installed, so as to keep an accurate record of core-oven temperatures.

NOTE. See index for heating core ovens with oil burners. (Fuel Oil Section.)

CORE NOTES

PRODUCTION NOTES.—To give the greatest production of cores per core maker per day, there must be no tendency for the core to stick to the boxes. In many cases where sticking is met with, it can be overcome by reducing the percentage of binder used.

In order to obtain the greatest production from the ovens, a quick-drying core-binding mixture should be used.

In steel foundries, the materials used for cores must not have any tendency to fuse at low temperatures, and the cores should give as the metal shrinks. Generally a binder such as glutrin, which, because of its tendency to come to the surface, due to sweating, produces a core with a hard skin and a soft inside, is used for cases involving high shrinkage.

In radiator foundries, the cores must be strong, so as to withstand the strain when they are surrounded with metal. They must also be free venting, and this also applies to stove-foundry cores. Sharp sand and oil, or oil and glutrin, are generally used.

In malleable- and gray-iron foundries, all kinds of core conditions are met with, but generally oil-sand cores are used, although, for some classes of work, flour or dextrin will be found in use.

In brass and bronze foundries, the temperatures encountered by the cores are lower than in the above-described foundries, but the main requirement is a core with a close surface. The sand should be free of clay. The core should be free venting, so as to allow for the gases to escape easily and the mould to be poured quickly. The binder should be capable of being burnt out at a comparatively low temperature. The cores in these foundries are sometimes blown out by dipping the hot castings into water, and the stream thus formed blows out the core. The melting temperature of brass and bronze mixtures is lower than that of iron alloys, and hence they remain fluid longer while in contact with the core. Sometimes an oil-and-flour binder is used.

In aluminum casting the metal has a high shrinkage, and the core should yield easily and soften as the hot metal comes into contact. Resin is often used as a binder.

ACTION OF ALKALI ON BINDERS.—Alkalies tend to cause saponification of oils, which impairs their binding power. Resin, glutrin, etc., are also affected. It is advisable, in investigating core-room conditions, to ascertain whether the water used in core making is pure.

CORE-HANDLING NOTES.—It is advisable to handle cores as little as possible while they are warm. In some foundries, where the cores are taken from the plates in a heated condition direct to the moulders, it is found necessary to use a comparatively greater percentage of binder, and, consequently, when the day is about over and the moulders require no more cores until the next day, thus permitting the cores to set, the percentage of binder may be reduced and a saving effected.

SECTION 10k

CUTTING AND DRILLING

CUTTING OPERATIONS FOR METAL

It has been generally taken for granted in the past that the lubricant applied to tools during the cutting operation flowed between the edge of the cutting tool and the work. If the enormous pressure which is required at the cutting edge of the tool, and which often exceeds 100,000 pounds per square inch, is compared with the maximum pressure of even 1000 pounds per square inch, which a lubricant, of as light a viscosity as that required for cutting-tool lubrication could stand, it can be readily appreciated that the lubricant does not form a film between the tool edge and the work.

When metal is cut, there is a large amount of heat generated. This heat is produced by the slipping of the metal chip over the face of the tool, by the separation of the chip or cut from the metal body, and by the "crimping" of the "cut."

THEORY

THEORY AND PRACTICE OF CUTTING OPERATIONS.—The cooling effect of the cutting lubricant, when it is properly applied to the cutting edge has a direct result upon the cutting speed. On the average, it can safely be estimated that when using high-speed tool steel and turning steel or wrought iron, an increase in the cutting speed of 30 per cent. to 35 per cent. will be possible, proportionate to the efficiency of lubrication.

As a general rule, the best results with a cutting lubricant will be obtained by applying it in the form of a heavy, slow-moving stream of good volume, rather than in a fast-moving stream. This result is due to the greater area, which can be covered by the lubricant when it is fed as a slow-moving stream, and also due to the reduced "splashing" effect.

In general, it has been found that, as the quality of the tool steel is improved, the possible percentage increase in cutting speed, when combined with efficient lubrication, is proportionately increased.

A matter of great importance is the point at which the stream of cutting lubricant should be applied. In order to obtain the best results, the stream should be directed on the exact area from which the chip is being removed. Very often in practice, the lubricant is allowed to flow onto the body of the work, rather than directly onto the "area of cutting."

Cast iron is usually worked dry, except when tapping. The dirt, which is caused by the fine iron dust mixing with the cutting lubricant, is objectionable. A soluble cutting lubricant will generally give better results for tapping this metal, than will a mineral-lard lubricant, because, with mineral-lard lubricant, the oil causes the chips to stick in the tap flutes.

For deep-hole drilling in steel, a mineral-lard oil is generally used, although a good supply of a low proportion soluble cutting lubricant will give good results. For turning steel, especially on automatic screw machines, mineral-lard cutting oil is widely used. If high speeds are to be met with, a well-directed stream of soluble oil emulsion will serve best.

Soluble oil emulsions give good results for "broaching steel." For "milling operations," either a mineral-lard or a soluble oil may be used.

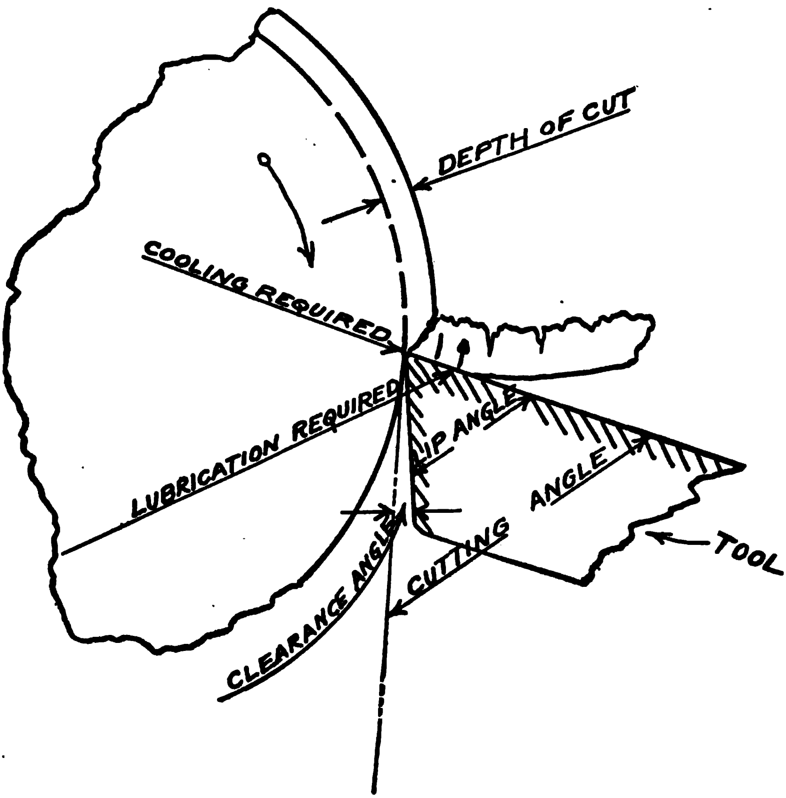

FIG. 1. SEC. 10*k*.—The operation of cutting.

The amount of lubricant required depends upon the type of operation. A single cutter may require only a slow thin feed, while a gang of cutters on deep work will require a flood of lubricant, particularly for carrying out the chips.

CUTTING OPERATION.—Fig. 1, Sec. 10k, shows the conditions under which the chip or cut is removed, and illustrates the need for a coolant and a lubricant. It is generally conceded, that there is metallic contact between the cutting edge and the work. Since friction is decreased

with increase in speed, it follows that frictional resistance between the lip of the tool and the chip is reduced, by increasing the cutting speed.

As is shown in the figure, the tool removes the chip by a shearing action.

The cost of power for cutting varies with the sharpness of the tool, the quality of the metal cut and the efficiency of the lubricant, all other factors being constant. (See index.)

There is no satisfactory method of determining the quality of the finish of the work from an accurate comparative basis. The operator can, however, tell from sight and touch whether the work is satisfactory, and can use a gauge and measurements to determine whether the tool has been kept up properly to its work. When two cuts are taken, one a "roughing cut" and the other a "finishing cut," the latter is usually much finer than the roughing cut, and the lubricant has, therefore, less work to perform in the finishing cut than during the roughing cut. For this reason, if it is satisfactory for the roughing cut, it will probably give results on the finishing cut, unless the oil impairs or rusts the work surface. The operator is paid either by the piece or by the hour or day. Since, in piece work, a profit is figured on each piece, the more work an operator can turn out, the more profit will be produced for the plant. The time of setting up the work will be the same under fixed conditions; therefore, the only way an increased production can be obtained is by running the machines faster, and by being required to stop less frequently for changing or grinding tools. There is, for any machine, a critical speed, beyond which it does not pay to run the machine, because the time of changing tools offsets any gain made by increasing the speed. The lubricant that will allow the tool to cut faster and not to fail in a stated time will also make the tool last longer if run at a fixed speed.

* No direct relation has been determined between the pressure on the lip of the tool by the chip and the life of the tool. Hard steel wears a tool faster than soft steel, but it has been proven that the pressure of the chip for hard steel is not necessarily more than for soft steel. When a roughing cut is taken, the chip usually bears on the tool a little way back from the cutting edge. The cutting edge merely smooths the work. This explains why cutting tools hollow out on the lip a little way back from the cutting edge, since the wear is at the point of greatest pressure.

REQUIREMENTS OF CUTTING OPERATION.—The cutting lubricant is expected to perform the following duties:

1. To lubricate the bearing formed between the chip and the lip of the cutting tool.
2. To cool the work and tool edge.
3. To flush the cutting operation, so that the chips will be washed away.
4. To aid in giving the completed work a finish.
5. To prevent rusting.

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* NOTE. The pressure per square inch of cross-sectional area of the chip increases slightly as the thickness of the chip decreases. The difference in pressure between slow and fast cutting speeds is slight, but the total power required to take off a given amount of metal is lower at the faster speeds. When cutting a hard metal the intensity of pressure per square inch of lip surface of the tool which comes in contact with the chip is greater than when cutting soft metals.

Fig. 2, Sec. 10k, shows a type of feed for use with hack saws and wide work. When using this feed with hack saws, the plate over which the lubricant is distributed should be placed against the plate of the saw. This type is useful for wide milling work also.

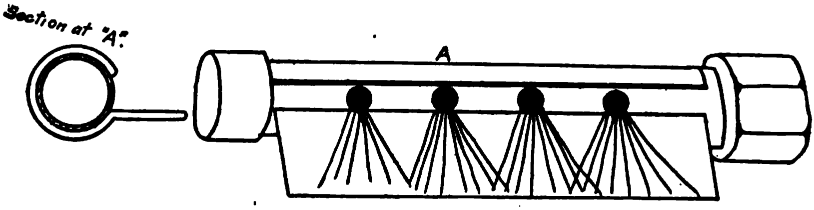

FIG. 2. SEC. 10*k*.—Plate type of feed for hack saws and wide work.

APPLICATION

APPLICATION OF LUBRICANT.—Fig. 3, Sec. 10k, shows four forms of feed outlets for supplying the lubricant to the operation. The type of the feed to be used is governed by the character of the work to be done and the type of tools used. In the figure, type *A* is known as the closed type of feed, and is used for milling cutters, overhead feed. Type *B* is known as the circular type, and is good for use with drills, end mills and heavy work in general. Type *C* is the open type, and is used for the same class of work as type *A*, but for horizontal feed. The type shown in the figure under type *D* is known as the multiple- or gang-feed type. It is useful for use with gang tools, and the feed at the different parts of the work can be independently regulated.

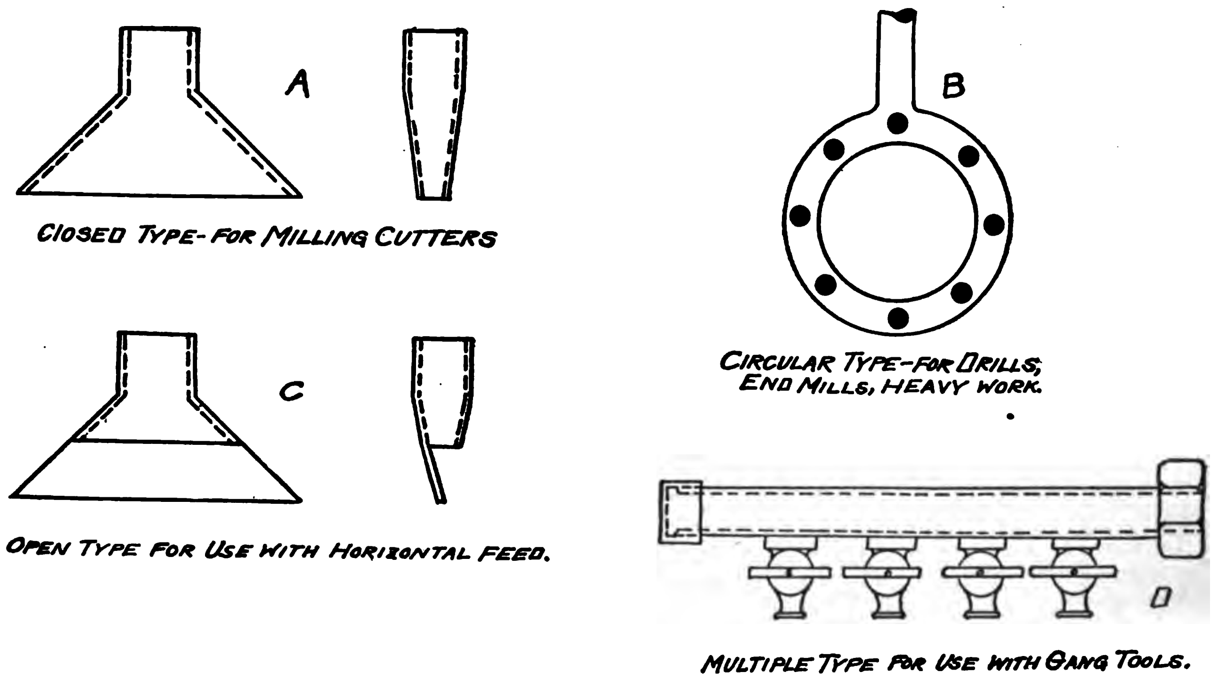

FIG. 3. SEC. 10*k*.—Typical feeds for cutting and milling lubricants.

MILLING OPERATIONS

LUBRICATION.—In the lubrication of the milling operation, we have a slightly different condition from that of the other cutting operations, in that the chips cut by the milling cutter are short, and the friction is, therefore, reduced between the cutter lip and the chip. The lubricant must, however, act as a coolant. The work is usually flooded, and in order to keep the lubricant from flying off, a shield is necessary to obtain the best results. These shields should drop down over the

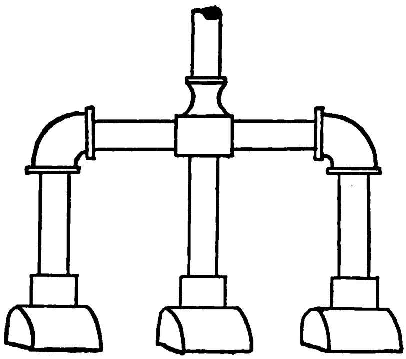

Fig. 4. Sec. 10*k*.—Feed for heavy milling-flooded lubrication.

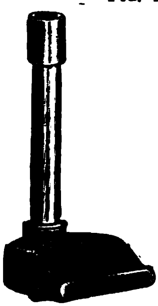

Fig. 5. Sec. 10*k*.—Distributer.

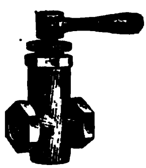

Fig. 6. Sec. 10*k*.—Valve.

Fig. 7. Sec. 10*k*.—Flexible tube swivel for base.

cutter, so that any lubricant which may splash up will be caught by the shields and returned to the work.

Fig. 4, Sec. 10k, shows a very satisfactory form of feed for heavy milling operations and flooded lubrication in general.

Air under some conditions has been found to be a satisfactory coolant for milling. By supplying an extra supply of air when milling cast iron, where the chips are very short, the heat can be absorbed. The air is delivered at about 1 to 2 pounds per square inch pressure at the machine. The pressure should not be high enough to scatter the chips too vigorously. There are some advantages in the use of air. It will not gum, cause rust or splash.

With milling cutters, the air can be delivered with success through ring-shaped feeds, perforated at frequent intervals and adjusted so that the air is delivered at a tangent to the work.

ACCESSORIES FOR MILLING-MACHINE CUTTING LUBRICANT.—Fig. 5, Sec. 10k, shows a distributer. Fig. 6, Sec. 10k, shows a valve for the distributer pipe. Fig. 7, Sec. 10k, shows a flexible tube swivel for the machine base. Fig. 8, Sec. 10k, shows a strainer for the

FIG. 8. SEC. 10*k*.—Strainer.

FIG. 9. SEC. 10*k*.—Distributer bracket.

FIG. 10. SEC. 10*k*.—Distributer swivel.

FIG. 11. SEC. 10*k*.—Check valve.

FIG. 12. SEC. 10*k*.—Relief valve.

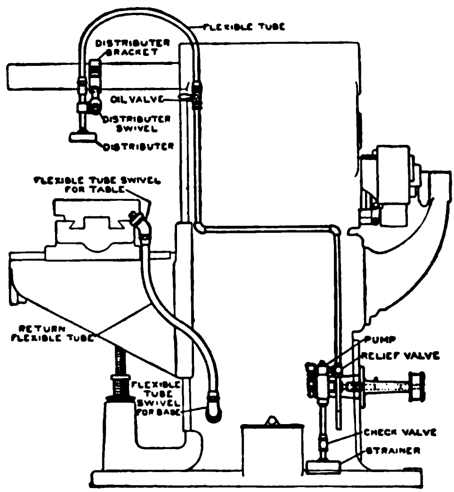

FIG. 13. SEC. 1C*k*.—Arrangement of oil piping for milling machines.

pump intake or suction. Fig. 9, Sec. 10k, shows a distributer bracket. Fig. 10, Sec. 10k, shows a distributer swivel for permitting the distributer to be adjusted in various directions. Fig. 11, Sec. 10k, shows a check valve for placing above the strainer in the pump suction. Fig. 12, Sec. 10k, shows a relief valve for putting in the delivery line.

Fig. 13, Sec. 10k, shows a milling machine equipped with the various accessories as above outlined, showing their proper location.

DRILLING OPERATIONS

DRILLING FRICTION.—Several investigators have measured the amount of friction developed during the drilling operation when using a lubricant and when not using one.

The results of one investigator are as follows: When lubricants were used in drilling with twist drills, using a feed of 0.04 inch per revolution, the torque was 72 per cent., and with a feed of 0.03 inch per revolution the torque was increased to 92 per cent. of the value obtained when operating dry; that is, without lubricant.

Another investigator found that lubrication reduced the end thrust on a twist drill 35 per cent. and the torque was reduced 20 per cent.

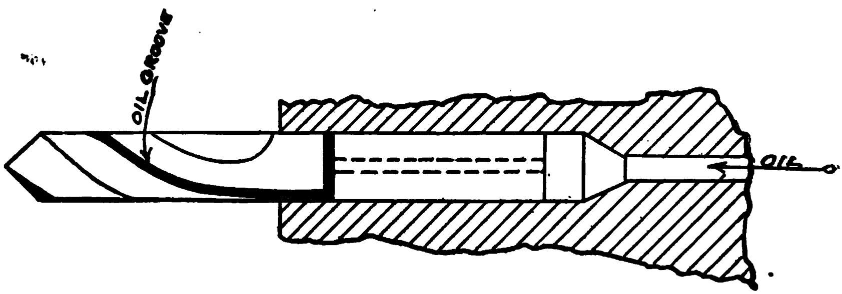

FIG. 14. SEC. 10*k*.—Drill with oil groove.

With a boring bar the following relative power consumption was obtained with different lubricants: Water gave 0.9; soap and water gave 0.94; oil and water emulsion gave 0.87.

When drilling soft steel, an engineer reports that the respective end thrusts were 26 per cent., 37 per cent. and 12 per cent. less than the thrusts when no lubricant was used.

A drill has been developed which has an oil groove cut in the face as is shown in Fig. 14, Sec. 10k. This oil groove delivers the lubricant well down into deep holes, and the resulting washing effect is important. The oil is delivered at high pressure, which for deep work may range as high as 800 to 850 pounds per square inch.

There is a wide variety of drilling machines, for drilling holes with flat, twist or other drills, for tapping, reaming, etc. Some typical types are: Radial, horizontal, sensitive, multiple spindle gang type, automatic revolving table, bench, etc.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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DRILLING SPEEDS

Diameter of drill, inches	R. P. M., soft steel	R. P. M., brass	R. P. M., cast iron
3/16	600	1200	750
1/4	425	900	550
3/8	280	600	360
1/2	200	425	266
5/8	160	360	213
3/4	130	280	172
7/8	120	240	148
15/16	110	230	138
1	95	205	120
1 1/4	75	165	95
1 1/2	60	140	80
1 3/4	45	110	68
2	40	100	55

NOTE. The proper speeds for drilling depend largely upon the material and vary according to the degree of refractoriness of the material drilled. A feed of one inch, in from 95 to 125 R. P.·M., is the maximum that should be attempted. At these speeds it will be necessary to use plenty of oil.

The advantages of high-speed drilling for small holes in addition to increased production are decreased breakage of drills, lessened heating effect, allowable rates of feed are increased and burring is reduced.

PRACTICAL TESTING

TESTING THE EFFICIENCIES AND ECONOMIES OF CUTTING AND DRILLING LUBRICANTS.—Soluble cutting oils and cutting compounds are generally used for the lubrication and cooling of drills. These soluble oils are dissolved in varying quantities of water, according to the work to be done.

Some oils selling at a low price per gallon, may work satisfactorily only when mixed with water, in the ratio of one to five; while other more efficient soluble oils, which may cost a little more per gallon, will do satisfactory work when mixed in ratios as high as fifteen parts of water to one part of oil, or more.

It is, therefore, desirable to establish a standard method of comparison for soluble drilling and cutting oils, so that the relative economies and efficiencies of these oils may be determined.

In the following sample test a method of operation is outlined which may be used as a guide in conducting comparative tests on several soluble oils, and the method of preparing a report on the results of the tests. Assumed conditions are taken as a means of illustration.

ECONOMY TEST

OBJECT OF TEST.—To compare the relative economies of three soluble drilling oils costing:

Oil *A*	33 cents per gallon.
Oil *B*	36 cents per gallon.
Oil *C*	45 cents per gallon.

OPERATION OF TEST.—The three oils were emulsified with water in such proportions as to bring the cost of each mixture to a standard price of five cents per gallon, as follows:

$$(A)\ \frac{33}{X+1}=5$$

X = Number gallons of water required to make emulsion cost 5 cents per gallon.

$$33=5X+5;$$

X $(A)=5\frac{3}{5}$ gallons water.

$$(B)\ \frac{36}{X+1}=5$$

$$\frac{36-5}{5}=X;$$

X $(B)=6\frac{1}{5}$ gallons water.

$$(C)\ \frac{45}{X+1}=5;$$

X $(C)=8$ gallons water.

Each of the oils was emulsified with the quantities of water as indicated above and was tested in practical drilling tests as follows:

Test No. 1

Using a one-inch drill and maintaining a constant feed and speed, as well as a minimum feed of emulsion to do the work, six holes were drilled in a steel casting to a depth of one inch, with each of the emulsions.

Test No. 2

One hole, using each emulsion, was drilled through a billet of open-hearth steel, using a one-inch drill, running at 150 R. P. M. and fed at a constant feed. (The billet was 4 inches in thickness.)

The following points were noted during each test:

(*a*) Average temperature of the drill.
(*b*) Average consumption of the emulsions.
(*c*) Condition of the drill on completion of the drilling.
(*d*) Defects or irregularities in the hole drilled.
(*e*) Any overheating or seizing of the drill.

Corrosion Test

Each emulsion was subjected to a corrosion test. This test consisted in suspending strips of highly polished steel in each of the emulsions and allowing them to remain for a period of two weeks. On removal, the test pieces of steel should show no corrosion upon their polished surfaces.

Emulsion Test

Small quantities of each of the emulsions were placed in clean glasses and allowed to stand for two weeks in a place where they were not disturbed. Any high percentages of separation were noted.

Summary of Tests

Emulsion	Ratio parts water to parts oil		Remarks and condition of drill	
	Test No. 1	Test No. 2	Test No. 1	Test No. 2
Oil *A*	$5\frac{3}{8}$–1	$5\frac{3}{8}$–1	Poor, seizing	Fair, overheating.
Oil *B*	$6\frac{1}{8}$–1	$6\frac{1}{8}$–1	Good, seized slightly	Good, no trouble.
Oil *C*	8.0–1	8.0–1	Good, satisfactory, good holes	Very good, no trouble.

Note. By comparing the tabulated results of the tests, it is easy to decide that Oil *C*, although costing more per gallon than Oils *A* and *B*, is the most economical and satisfactory in service, because it gives the largest and most efficient emulsion per gallon of oil.

GRINDING OPERATIONS

GRINDING LUBRICATION.—The lubricant used for grinding "lubrication" may lubricate to some degree and reduce the friction of the cutting particles on the wheel, but it also has other important functions, namely:

(*a*) It eliminates the grinding-dust evil, as the lubricant carries away the dust.

(*b*) It keeps the temperature of the work more uniform over the entire surface of the cylinder, by distributing the "cutting heat."

(*c*) It carries away the heat generated by the wheel when cutting particles from the work, and thus redures the power required for grinding.

GRINDING NOTES.—Originally all grinding was done dry.

As an improvement, first a few drops of water were used, then a small stream was allowed to run on the wheel, and as more work was done, it is now good practice to allow a large stream of lubricating compound to flow on the wheel where it comes into contact with the piece being ground.

Clear water was first used, and then, because of rusting, soda water was substituted. Soda is a lubricant, and an improvement was noticed. Then soapy water and other compounds consisting of oil, soda water, soap, etc., were developed. Perhaps even better results would be obtained from clear oil if it were more universally used.

When work is ground dry, very light cuts must be taken in order to prevent excessive heat from being generated and causing harm to the work. This heat, due to the slow revolution of the work, will accumulate and produce warping.

It is impossible, under a heavy cut, to grind round and perfect cylinders. Enough grinding compound must be used to dissipate the heat. The term "grinding lubrication" is a misnomer.

GRINDING WHEELS.—Grinding wheels are made from commercial abrasives, carborundum, emery, alundum, etc.

Wheels glaze when they are too hard. To renew the surface and expose fresh, sharp grains, the wheel is "dressed."

Under the microscope the particles of metal removed by an abrasive wheel show the shape and character of chips similar to those cut by a lathe tool from the same material, thus indicating that grinding is a true cutting process.

CUTTING LUBRICANTS

LARD OIL.—This is the oldest form of cutting lubricant. Usually it is applied with a squirt can directly upon the work. Sometimes the drip-can method is used.

The main objections to its use are:

(*a*) The free fatty acid, developed in the oil, particularly when exposed to the cutting heats. This acid will attack metal, if allowed to remain in contact.

(*b*) The deterioration of the oil, particularly in its cooling effect, when it is re-used over again, several times.

(*c*) The high cost of the oil.

When used for brass cutting, it is very difficult to remove the fine dust from the oil after passing over the work.

SPERM OIL.—Sperm oil is sometimes used as a cutting lubricant for chucking and turning tool steel and also for drilling tool steel. It is undoubtedly an efficient lubricant, being free flowing and possessing great lubricating qualities, but its high price and other factors are against its use.

MINERAL-LARD OILS.—These oils are composed of a mineral oil of low viscosity, compounded with a fatty oil, such as lard oil.

They generally contain from 10 per cent. to 25 per cent. of lard oil. the percentage amount depending upon the type of the cutting operation and the cutting speeds to be met with.

They can be successfully used for turning, drilling, reaming, chucking, tapping, and milling steel and wrought iron.

A typical mineral-lard oil to be used for general work would have the following specifications:

Not less than 380° Fahr. flash (open cup).
Not above 35° Fahr. cold test.
To contain not less than 25 per cent. nor more than 30 per cent. lard oil, and not to contain more than 5 per cent. free fatty acid, calculated as oleic acid.
Viscosity about 130 to 180 Saybolt at 100° Fahr.
Should show no corrosion on a plate of polished steel, when it is immersed in it for a week, and should work equally well unadulterated, or when mixed with kerosene or soda water.

A mineral-lard oil especially adapted for general use on high-carbon steel had the following tests:

25 per cent. lard oil.
180 Vis. at 100° F.
400° flash.
30° F. cold test.

A mineral-lard oil especially suited to be used in circulating systems, for fast cutting, where a generous supply of the lubricant was supplied, had the following tests:

10 per cent. lard oil.
180° Vis. Say. at 100° F.
400° Fahr. flash.
28° F. cold test.

For heavy, coarse work, the oil should have plenty of body to lubricate the sliding action of the chip, over the lip of the tool. A typical mineral-lard oil for this purpose and for pipe-thread cutting will have the following general specifications:

25 per cent. lard oil.
25° grav.
250 Vis. Say. at 100° F.
390° flash.
46° F. cold test.

A fatty-oil compound is particularly valuable in adhering to the metal and resisting the wiping action.

SPECIFICATIONS FOR MINERAL-LARD OILS.—Mineral-lard oils must be clear and homogeneous. They should be free from all disagreeable odors that would tend to make the workmen sick. They should show no signs of rancidity or contain any sediment.

A method for testing the "gumming action" of a mineral-lard oil may be described as follows: A glass tray with its bottom covered with the oil is exposed to an even heat of 212° Fahr. for eight hours and then cooled. It should show no signs of a gummy residue or excessive free acid. In no case should the oil test more than 5 per cent. free fatty acid, calculated as oleic acid.

When strips of polished steel are partly immersed in samples of the oil for a period of two weeks, there should not be any evident signs of corrosion.

FIXED OILS AS CUTTING LUBRICANTS.—It must be remembered in connection with fixed oils as cutting lubricants that when these oils are subjected to high heat, as found in the "cutting area," the oils tend to undergo a change and turn rancid with the liberation of fatty acids and development of disagreeable odors. The thickening up of these oils on development of rancidity generally results in gumming and clogging of the feed pipes.

SOLUBLE CUTTING LUBRICANTS

THE VALUE OF SOLUBLE CUTTING LUBRICANTS.—Of all liquids available for the "lubrication" or cooling of the cutting operation, water has the highest heat-absorbing qualities. It can also be readily flowed into contact with the heated surfaces, but, due to its low viscosity, it will not form a satisfactory lubricating film for the sliding of the chip over the face or lip of the tool. The rusting properties of water also make it unsuitable as a cutting lubricant, when used alone.

Petroleum oil, cottonseed oil, and lard oil have the required body to form the necessary film on the tool lip, and, while their specific heats or heat-absorbing properties are only about half as high as water, they have the property of preventing rusting.

The so-called soluble cutting oils are usually mineral oils, held in suspension by soaps or alkalies, or sulphonated oils, based on the solubility of sulphonated fatty acids.

The amounts of water required with soluble oils vary with the character of the work. For tough steel, a larger amount of oil is used than for the more brittle metals, since the steel chips press against the face of the tool with greater force and for a longer distance.

"SOLUBLE OILS"; SOAP-BASE TYPE.—These oils consist essentially of unsaponifiable oil, saponifiable matter, alkali soap and water in various proportions. They should be readily miscible with water and should maintain a stable emulsion (also see p. 652).

* One method of making a soluble oil is as follows:

Elaine or oleic acid is saponified with water and sodium hydrate (32–40° B.). This is cooked to soap and clarified with wood alcohol, the amount depending upon the strength of the oleic acid, or it may be brought up with sulphuric acid (28° B.), or acetic acid (56° B.); then mineral oil is added and will be taken up. The alcohol will keep the oil clear and bright. The oil produced should be clear and homogeneous and should consist of between 20 per cent. to 30 per cent. of soluble alkali soap. It should be free from mineral acids, free alkali and disagreeable odors. Soluble oil when dissolved in water should be practically neutral. For the mineral-oil content, the trade usually uses a 28° B. or a 25° B. paraffin oil. In the case of these oils made miscible with alcohol, the tendency of the alcohol to evaporate off may allow a separation of the emulsion formed, since the action which holds the molecules of oil in suspension in the water is then reduced.

Another Method.—Resin oil, saponified with borax and cooked until the water is evaporated, usually over steam, because of resin fumes, will then take up mineral oil. About two pounds of borax to a gallon of resin oil is used, and amounts of mineral oil, such as 28 paraffin oil, in proportions of from 10 to 12 pints.

This type of soluble oils should remain slightly on the alkaline side. This is the reason that ammonia, potash or soda is sometimes recommended to be added in small quantities, in order to help the emulsion. When the water used with these oils is taken from a river and only

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* NOTE. Another formula is: 7.6 per cent. blown rape oil, 6.6 per cent. degras, 3 per cent. 40° potash, 4.8 per cent. W. W. resin, and 78 per cent. of 210 Vis. Say. at 100° Fahr. red paraffin oil.

partially clarified, it is full of impurities, especially in the spring months after the winter thaws. Distilled water or soft water will improve the emulsions made with these oils very much. The difficulty with these oils when hard water is used is to get a perfect emulsion, free from curds. The curds are due to the formation of a lime soap, which is insoluble in water. It is a good plan to draw the water the night before the mix is to be made, and let it stand in a barrel, and tap it off when ready to use, a few inches above the bottom, so that when the water is drawn off the sediment will remain. If this does not answer, add 1/2 to 1 pound of soda ash to 50 gallons of water, thoroughly agitate the soda ash and water for about 10 minutes, then stir in the oil.

Some plants mix the oil and water hot. Care must be taken in this case not to barrel the mixture too soon, as there will be a tendency to melt the glue in the barrel, and, while glue is not soluble in the oil itself, it will float on the surface in small particles. These will choke up the feed pipes. (See index for other references to water.)

* **SULPHONATED OILS.**—Sulphonated oils may be used as a base in the manufacture of soluble cutting lubricants. Sulphonated oils are oils that have been treated with sulphuric acid. The excess sulphuric acid being washed out, and only that which is combined organically with the glyceride permitted to remain. After this operation, the oil is neutralized with an alkali, either soda or ammonia, or a combination. An oil of this nature, when properly sulphonated, should make a solution in water having a slight opalescence. Castor oils give the best results with regard to the action of the sulphuric acid. Other oils, such as corn oil, may be added to the castor oil to reduce the cost. This is then worked in with mineral oil. The following description may be of interest, with regard to making a soluble oil of this type:

17	per cent. of cordage oil. { 80 Vis. at 100° F. / 34 Grav. at 60° F. / 350 Flash. }
8	per cent. red oil (or commercial oleic acid).
13.5	per cent. of sulphonated oil (castor and corn oils).
4.5	per cent. of 10° B. caustic soda solution.
25	per cent. sulphonated castor oil (60 per cent.).
32.0	per cent. of water.
100	per cent. (The percentages are according to weight.)

The process of making this oil is to mix the cordage and sulphonated castor oil and stir. Then the caustic soda is added, while agitating, and the mixture is brought to the boiling point and allowed to stand for about 12 hours. The sulphonated castor oil and corn oil is next added and mixed by stirring. A sample is then tested, to determine whether it is perfectly soluble, and, if not, more caustic potash is added. The oil is next tested for stability, by chilling a sample and observing whether it remains clear. If it does not remain clear, a small additional amount of the sulphonated castor and corn oil is added. Water is next added.

WATER AND COOLING.—The use of heavy streams of water

* Another type, known as a Sulphurized Base, is also marketed.

directly thrown upon the chip at its point of separation, in the case of high-speed tools shows a gain of about 40 per cent., for carbon-steel tools about 23 per cent. and for self-hardening, old-style steel tools, about 30 per cent. About 3 1/2 gallons per minute should be used for a 2 x 2 1/2-inch tool.

ECONOMICAL USES.—In large plants care must be exercised to make sure that the workmen mix the soluble oil and water in economical proportions, as it is very common to find that some workmen carelessly use too small a percentage of water. This involves large monetary loss if unchecked.

There is a patented device designed to mix soluble oils and water in any desired proportions, and in all quantities of finished emulsions, which can be set by the foreman in charge, and thereafter absolutely turns out a uniform mixture. This is a valuable apparatus in any plant, and in one place, coming under the writer's notice, a saving of $3575 was made in one year by its use.

DATA ON "SOLUBLE OILS"

CHARACTERISTICS OF SOAP BASE TYPE SOLUBLE CUTTING OILS.—Three oils having the following general analysis were compared from the standpoint of efficiency, as follows:

(Analysis in per cent.)

	Oil No. 1	Oil No. 2	Oil No. 3
Unsaponifiable oil	47.3	72.3	55.5
Saponifiable oil	29.6	16.8	11.1
Alkali soap	15.8	8.4	22.0
Ash	3.37	1.77	2.94
Water	7.3	2.5	11.4
Alkalinity (Na_2O) equivalent	1.2	0.8	1.00

Under the same practical testing conditions, for drilling purposes, the following results were obtained:

1. Oil No. 1 gave a high temperature rise and showed a separating tendency and a gummy residue. It showed no corrosion.
2. Oil No. 2 gave a small temperature rise and only a small gummy residue. The separation in the two oils was probably due to the use of caustic soda, instead of potash in the solution.
3. Oil No. 3 gave a small temperature rise, no gummy residue and no signs of corrosion.

REQUIREMENTS OF GOOD SOLUBLE CUTTING LUBRICANTS.—They must be free from disagreeable odors, mineral acids, and ingredients, which are injurious to the workmen's hands. They should show no tendency to leave a sticky residue, and should form a stable emulsion with cold water, in any proportion, without the use of any other product. They must be free from corrosive action on polished metals. They must possess good cooling qualities.

CUTTING COMPOUNDS

CUTTING COMPOUND, PASTE FORM.—A cutting compound in the paste form can be made as follows:

10 pounds of paraffin oil, 25 gravity.
5 pounds of No. 2 lard oil.
10 pounds of Paraffin oil, 25 gravity.
25 pounds of caustic soda solution, made by dissolving 2 1/4 pounds of 76° caustic soda in 4 gallons of water.

These should be mixed with the oils at about 110° Fahr. and the caustic solution at about 90° Fahr. To cheapen the cost, about 30 pounds of water may be beaten into the paste.

CUTTING-COMPOUND ANALYSIS.—A cutting compound that gave good results consisted of the following approximate analysis:

47.83 per cent.: Paraffin oil, 100 to 105 Vis.; 363 Flash.
34.78 per cent.: Water.
15.56 per cent.: Elain.
1.83 per cent.: Caustic soda (compounded by weight).

GENERAL DATA.—Paste-form cutting compounds are combinations of oils and soaps. These pastes are generally used where the work is large, and particularly when portable tools are used, such as for reaming boiler plates for expanding tubes. Under such conditions an oil or other liquid is not utilized because of the cost and the difficulty of application. Paste-form lubricants possess but little cooling effect as cutting lubricants. Pastes that are especially manufactured for the purpose are mixed with water to form a soapy emulsion, and used similar to other emulsions, being favored for large rough work where cheapness is a factor. They must usually be mixed with hot water, and frequently stirred to prevent separation.

NAVY DEPARTMENT SPECIFICATIONS FOR CUTTING COMPOUND, PASTE FORM.

PURPOSE.

2. To be used for machine-cutting-tool lubricant when mixed as directed.

COMPOSITION

3. To be a soluble paste compound consisting of an alkali soap, mineral and fixed saponifiable oils and water. To be free from disagreeable odors, mineral acids, or any ingredients injurious to persons handling the material.

To contain not more than 25 per cent. of water, not more than 20 per cent. of alkali soap, not less than 40 per cent. of mineral oil, and the remainder fixed saponifiable oil. It must form a stable emulsion when mixed with water.

LUBRICATION

4. The emulsion must sufficiently lubricate turret and automatic machines to prevent sticking, the solution used to be suitable for work being performed on the machine, and must show no tendency to leave a gummy residue.

CORROSION

5. Strips of polished steel are to show no appreciable corrosion after being partly immersed in mixture for a period of two weeks.

PHYSICAL TEST*

6. One pound of the paste will be put into emulsification with 3 gallons of water and the emulsion permitted to flow at the rate of 1 gallon per minute over a steel cylinder heated by an electrical coil consuming 440 watts which maintains a constant temperature of 100° C. in air. After a period of 8 hours, the maximum rise of temperature of the emulsion shall not exceed 12° C. This physical test will be conducted at the New York Navy Yard on samples before approval on the standard apparatus shown in drawing No. 36367-A, which may be obtained from the Engineer Officer at the Navy Yard, New York.

* NOTE. Recently changed.

FORM 1 HP

SECTION No.________

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
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SODA MIXTURES.—A soda mixture for machine tools in use by a large railroad is made as follows: Dissolve 5 pounds of common sal soda in 40 gallons of water and thoroughly mix it. When ready to use, mix the soda solution with 1 pint of extra No. 1 lard oil and 2 pints of paraffin oil of 24° to 26° gravity Baumé, 300° Fahr. flash, 30° Fahr. cold test.

Another soda mixture which is recommended by some shops is prepared as follows:

40	gallons of water.
10	gallons of mineral-lard oil.
2 1/2	pounds of soda ash (no more or no less).
10	ounces of borax.

The soda ash is weighed (caustic soda or caustic potash will not do), and dissolved with the borax in a bucket of hot water. This is put into a clean tank and thoroughly mixed for 30 minutes and the mineral-lard oil then added, when, upon mixing, the solution will form a milky emulsion. Soda and water is better than clear water, especially with ferrous metals, as the soda acts to prevent rust. When mineral oil is mixed in as above noted, trouble may be experienced, due to the non-homogeneous character of the mixture.

SPECIAL PRODUCTS.—A soft form of grease, carrying an excess of fat, made with a mineral cylinder stock, is found on the market. It is recommended by the makers as a base, with which varying quantities of light lubricating oils can be mixed, to produce cutting fluids of different viscosities, as required by the character of the work.

TESTS ON CUTTING LUBRICANTS

COMPARATIVE TESTS ON VARIOUS CUTTING LUBRICANTS.—Fig. 15, Sec. 10k, and Fig. 16, Sec. 10k, show curves, plotted from results of comparative tests to determine the lubricating value of various cutting lubricants, in connection with thread cutting. The points studied were the cooling effect of the different lubricants during the cutting operation and the quality of the work produced when the individual lubricants were used.

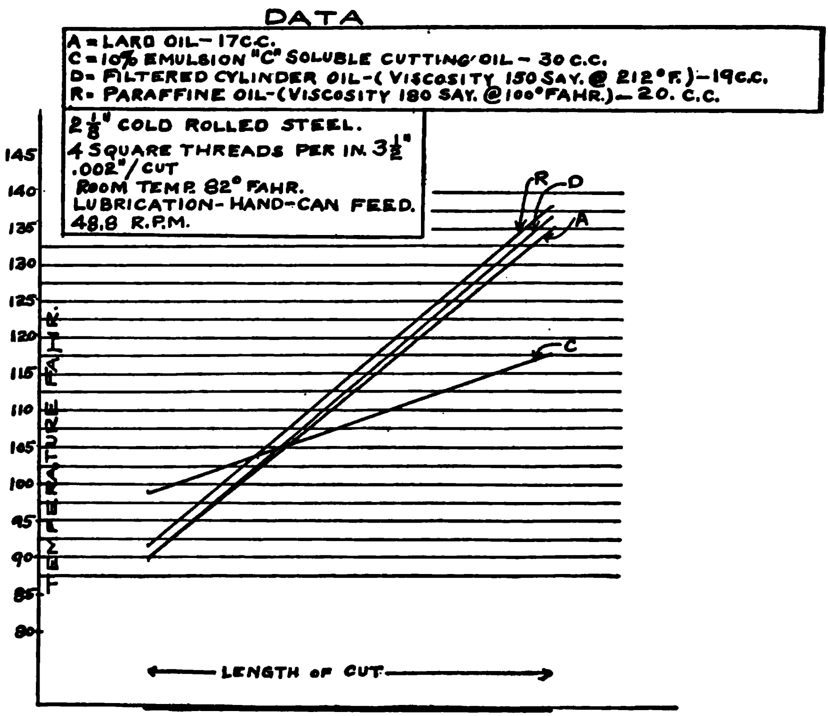


FIG. 15. SEC. 10*k*.—Cutting oil test No. 1.

The curves shown in Fig. 15, Sec. 10k, were the results of a test on a 2 1/8-inch cold-rolled steel bar. A square thread (4 threads per inch) was cut for a distance of 3 1/2 inches, at a speed of 48.8 R. P. M. A hole was drilled lengthwise through the centre of the piece of steel, and a thermometer was inserted to measure the temperature. The various lubricants were applied by the operator from an ordinary hand oil can, at such intervals as he thought best from actual experience; thus the practical working factor, as would be obtained in the field, was obtained.

The curves shown in Fig. 16, Sec. 10k, were obtained from the same sort of test as outlined above, except that the lubricants were applied

from a drip can, giving a flood feed. Owing to the different "sticking" qualities of the various lubricants, different rates of feed were required when the different lubricants were used. The main idea was to obtain the best possible results from the standpoint of the finished work. The emulsions, of course, freely run off of the work, while the heavy oils stick. This is not an objectionable feature, but in some respects is an advantage for the emulsions, in that the work is kept in such shape that the mechanic can better see the progress of the work, and also the free-flowing action increases the "heat carrying away" factor." Of course,

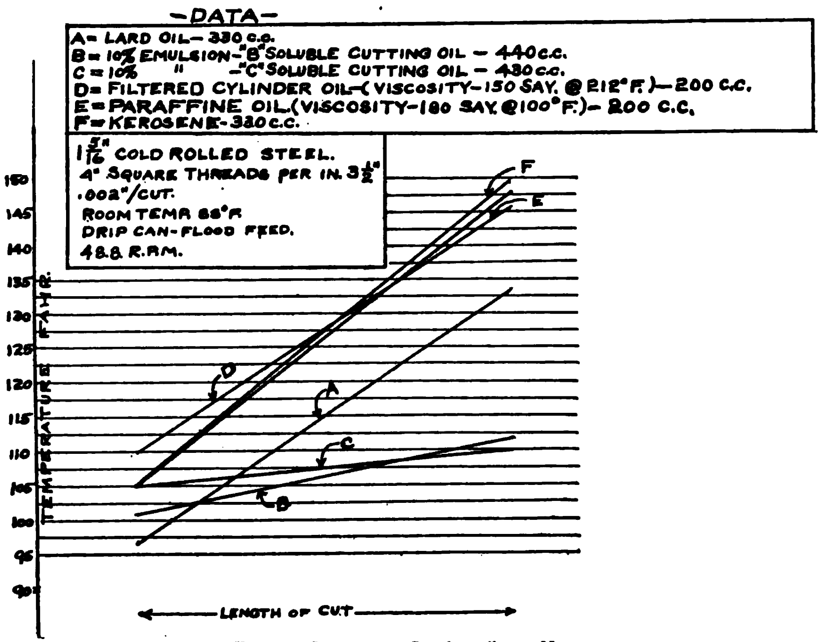


FIG. 16. SEC. 10k.—Cutting oil test No. 2.

the "sticking to the metal" feature, in the case of the lard and the heavy oils, is important in respect to lubricating the sliding action of a heavy chip over the lip of the tool. The increase in temperature, while using the different lubricants, is plotted against the time of the cut. The emulsions show the least increase, thus demonstrating their superior cooling action. The cooling action of the mineral and lard oils is less, and show for the individual oil very little difference.

It will be noted that in the second test, where the drip can or flooded lubrication is used, the operating temperatures are not very different from those obtained from the hand-feed test. This is probably due to the larger size of the pieces in the first test, which transmitted the heat slower to the thermometer, and which also had a larger radiation surface. The

cut surfaces were examined, and in the first test they were graded as follows by two independent observers:

1. " C " soluble cutting-oil emulsion, 10 per cent. mix.
2. Lard oil.
3. " R " paraffin oil.
4. " D " filtered cylinder stock.

In the second test the grading of the work was as follows:

1. " C " soluble cutting-oil emulsion, 10 per cent. mix.
2. " B " soluble cutting-oil emulsion, 10 per cent. mix.
3. Lard oil.
4. Kerosene.
5. " E " paraffin oil.
6. Filtered cylinder stock (D).

The condition of the surfaces produced by lubricants Nos. 3, 4 and 5 showed very little difference.

LUBRICANT SUPPLY AND TREATMENT

METHODS OF CUTTING-LUBRICANT SUPPLY.—There are three main types of cutting-lubricant feed systems:

(*a*) The drip-can method.

(*b*) The circulating system, self-contained, with a tank in the base of the machine, and equipped with a circulating pump.

(*c*) Circulating systems, with settling tanks, separating devices for removing the oil from the chips, pumps, and sterilizing tanks. The entire system, with the exception of the draining or collecting pans, being located exterior to the machines.

The main parts of an up-to-date cutting-lubricant supply system may be classified as follows:

1. The supply	(*a*) Gravity feed from tank or can. (*b*) Pumped to outlet.
2. The collection of the chips and oil	(*a*) By a can underneath the table. (*b*) By a tank, pan or tray. (*c*) By chutes or troughs. (*d*) By a hollow base in the machine.
3. Separation of oil from chips	(*a*) By strainers. (*b*) By flowing the mixture over dams or weirs. (*c*) By centrifugal separators.
4. Cooling of the lubricant	(*a*) By providing a reserve tank, to alternate feed from. (*b*) By providing a large surplus of lubricant storage space, to give the oil a rest. (*c*) By artificial cooling.
5. Sterilization	(*a*) To prevent sores on the workmen's hands. This is usually done with heat.

METHODS OF HANDLING CUTTING AND DRILLING LUBRICANTS.—In the average plant, when the cutting oil becomes too dirty for further use, it is thrown away. This is a very wasteful and unnecessary practice. The modern shop is, however, becoming more careful of the many wastes and leaks, and in many of these places filters and continuous-supply systems have been substituted for the old-style methods.

In shops, where it is impracticable to have a filter at each machine, the usual small circulating pump on each machine is disconnected and the filtration of the cutting lubricant is done on the group plan. In this plan the oil flows over the work of a number of machine tools, and then flows into the base of each machine. From these bases it is piped, or is carried by concrete trenches, to the central filter. Here it is purified and then pumped to an overhead storage tank, so that it can flow by gravity to the various machines, or it is pumped directly to a supply line, which has branches leading to each machine. In the latter case, the pressure is controlled by a regulating valve, so that the pressure will be the same at all times. The latest practice is to install a motor-driven triplex pump for pumping direct to the machines, while for the gravity-feed system, any kind of pump, such as a rotary centrifugal may be used.

In case the machines are grouped or are too far apart in the shop to make the central system practical, it is more economical to use a small central filtering system for each group of machines.

Fig. 17, Sec. 10k, shows the outline of the piping for a system for purifying and circulating cutting oils.

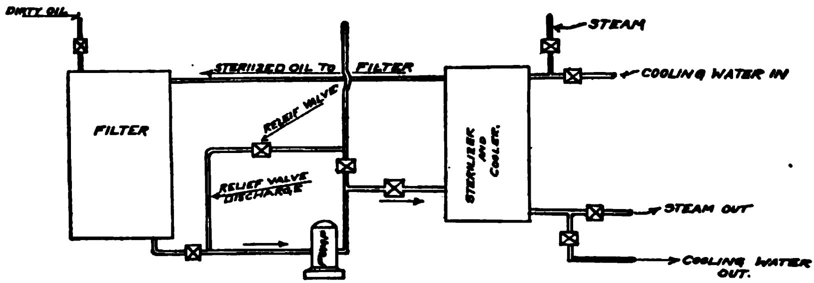


FIG. 17. SEC. 10k.—Piping diagram for continuous oiling system for cutting lubricants.

In some cases, centrifugal separators are used to free the oil from the chips. It has been estimated that 30 pounds of chips will hold a gallon of mineral-lard oil. Thus it can be appreciated what a large waste may occur in those plants where the chips are removed without cleaning them from oil. Experiments have shown that 140 pounds of chips will hold 1 gallon of kerosene. Usually the chips are drained before being placed in the centrifugal separator. A grid makes a good drain.

CUTTING OIL RECLAIMING SYSTEMS.—The subject of reclaiming cutting oils, after they have passed over the work, has been developed to a highly efficient degree. The system shown in Fig. 18, Sec. 10k, was especially designed for the purpose of illustrating the operation of such a system by S. F. Bowser & Co., Inc. This system is similar using automatic machinery. The capacities and size of equipment for several systems such as this are as follows:

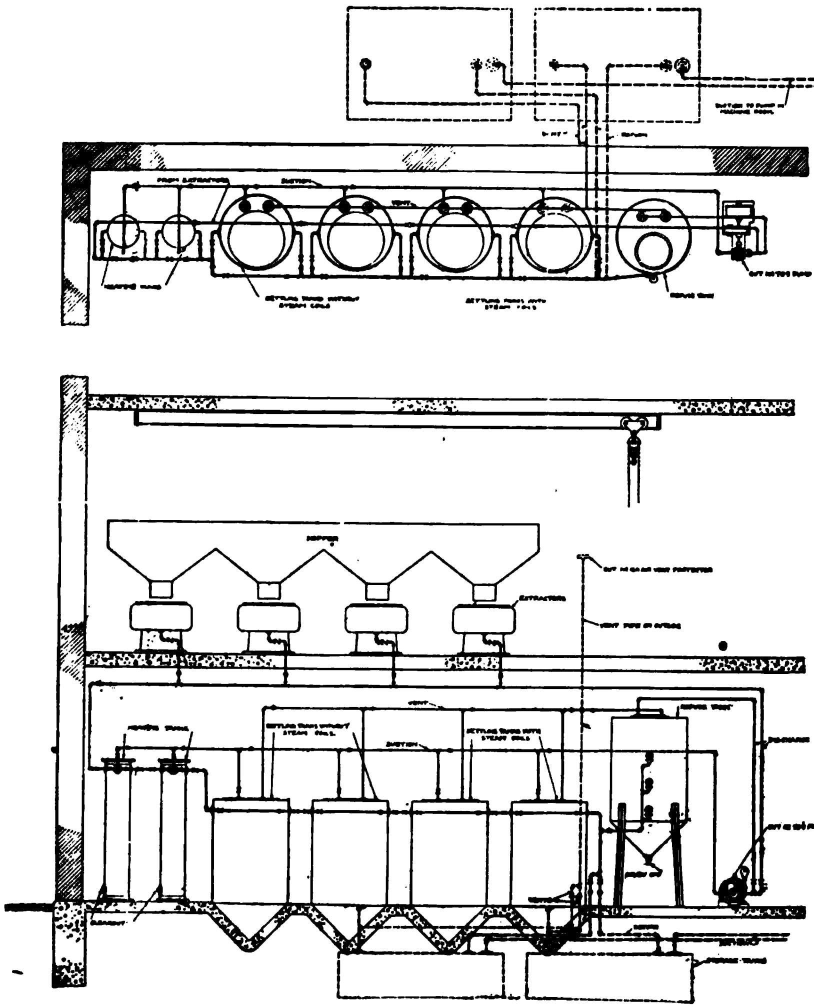


FIG. 18. SEC. 10k.—Cutting oil reclaiming system.

Capacity of Systems

FROM 100 TO 299 GALLONS IN 24 HOURS

Two 35 U. S. gallon tanks with steam coils.
Two 120 U. S. gallon tanks with steam coils.
Two 120 U. S. gallon tanks without steam coils.
One 120 U. S. gallon refuse tank.
Two 300 U. S. gallon storage tanks.
One pump.

FROM 300 TO 499 GALLONS IN 24 HOURS

Two 35 U. S. gallon tanks with steam coils.
Two 220 U. S. gallon tanks with steam coils.
Two 220 U. S. gallon tanks without steam coils.
One 220 U. S. gallon refuse tank.
Two 500 U. S. gallon storage tanks.
One pump.

FROM 500 TO 909 GALLONS IN 24 HOURS

Two 35 U. S. gallon tanks with steam coils.
Two 280 U. S. gallon tanks with steam coils.
Two 280 U. S. gallon tanks without steam coils.
One 280 U. S. gallon refuse tank.
Two 1000 U. S. gallon storage tank.
One pump.

Referring to Fig. 18, Sec. 10k, there are shown:

1. Two heating tanks.
2. Four cone-bottomed settling tanks.
3. One cone-bottomed refuse tank.
4. One cylindrical tank for the storage of new and reclaimed oil. (In some cases two tanks are provided.)
5. One power pump, for handling the oil throughout the system.
6. Four extractors and bins.
7. Necessary piping and fittings.

Fig. 19, Sec. 10k, shows a view of the reclaiming system.

The capacities of the hopper-bottomed tanks, the refuse tank and the cylindrical storage tanks are varied, to meet operating conditions, while the capacities of the heating tanks remain the same for all ordinary conditions.

The operation of this system is as follows (see Fig. 18, Sec. 10k):

1. The oil and chips are put into the hopper-bottomed tanks, and pass from there to the centrifugal extractors (see Fig. 20, Sec. 10k), in which separation of oil from the metal chips is accomplished. A chain hoist is provided, as shown on its track, for conveying the oily chips to the hoppers.

2. The oil now enters the first of the two heating tanks, from a flange at the top of the tank, and flows downward, through the interior pipe-line, to the bottom of the tank.

3. It next overflows from the top of the tank, at a point nearly opposite the entrance point, into the second heating tank, which is identical with the first heating tank.

4. The oil then passes through the overflow from the second heating tank into the first of the settling tanks (hopper-bottomed).

5. The oil enters the first of the series of settling tanks and flows downward, through the interior pipe line, to a point at a level with the top of the cones. It overflows into the next settling tank, at a point opposite that of entrance, and so on through the series of settling tanks. The general piping arrangement for entrance and exit of the oil is similar for the heating tanks and settling tanks. It can thus be said, that the oil

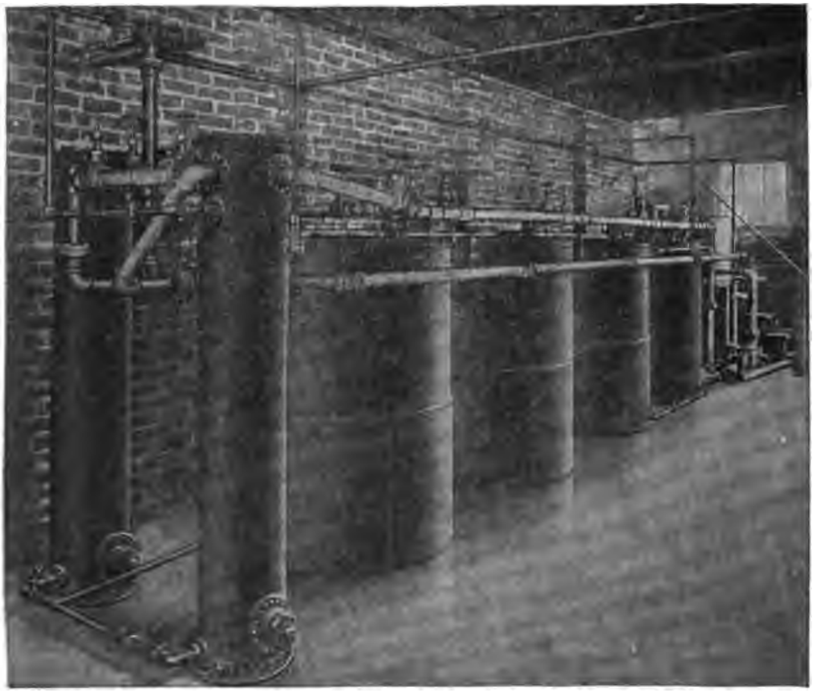


Fig. 19. Sec. 10k.—Cutting oil reclaiming system. Rated capacity 1700 gallons per day.

passes through the cone-bottomed settling tanks in series. The last two tanks are equipped with steam coils, to aid the further heating precipitation. They may also be used for the purpose of further sterilizing the oil.

Each of the settling tanks is provided with a large cap-bolted manhole, to facilitate thorough cleaning or inspection, while the heating tanks are provided with clean-out openings, at the bottoms of the tanks.

6. By means of a rotary pump, the oil is transferred from the bottom of any one of the settling tanks to the refuse tank. The suction line in each tank reaches very nearly to the bottom of the cone, so that the heavy sediment, which has accumulated during the settling process, may be

withdrawn into the refuse tank, where further precipitation takes place. The final worthless deposit is drawn off from a cock at the vertex of the cone bottom.

On the side of the refuse tank there are provided a number of valves, which are used for sampling valves. They communicate with a pipe line, which returns the clarified oil to one of the two storage tanks for reclaimed oil, while the other is reserved for strictly new oil. The piping is so arranged, however, that the reclaimed oil can be reclaimed to either tank. The sampling valves permit a very small quantity of oil to be withdrawn, the sample showing to what extent precipitation has taken

FIG. 20. SEC. 10*k*.—View of extractors for separating chips from cutting oil, reclaiming system.

place to the level of that valve. If sediment is still found in the sample, the valve is closed and further time is allowed for precipitation. If the oil is found to be clarified, the entire supply in the refuse tank, down to the level of that sampling valve, is allowed to return to the storage tank. The process is repeated with the other two sampling valves, the operation being governed, of course, by the amount of oil in the refuse tank.

It can thus be seen that the function of the refuse tank is to carry the reclaiming process to the farthest extent possible, by further precipitating the settlings, highly charged with impurities, which are pumped from the cone bottoms of the settling tanks. The refuse tank, like the settling tanks, is provided with a cap-bolted manhole (through which the pipe lines enter) to facilitate cleaning.

FUNCTIONS OF THE TWO HEATING TANKS

1. To render the oil more fluid, by raising its temperature, thus facilitating precipitation. This operation is accomplished by means of a spiral heating coil in each tank.

2. To sterilize the oil, when desired. In reference to the sterilizing process, it can be said to be one of the most important features of the system. (See section on Bacteria in Cutting Oils.)

PIPE LINES OF SYSTEM

The pipe lines are so arranged that the oil may be pumped from any tank, and also so that either one of the heating tanks, or any one of the settling tanks may be shut off from the system, by by-passing. This makes it possible to clean any one of the tanks, or make repairs to valves, etc., without shutting down the system. Any one of the two heating tanks and settling tanks, which are equipped with steam coils, may be temporarily disconnected from the system and used as a sterilizing tank. The operation of sterilizing can also be conducted during periods when the system is at rest.

STORAGE TANKS

It is customary to place the cylindrical tanks used for storage of the reclaimed and new oil underground. In such cases steam coils should be provided in each tank, to insure proper temperature conditions. A fill pipe for outside filling is provided on each tank. A venting system is also shown. The oil may be delivered from the storage tanks by means of either a hand pump or a power pump. Some systems are equipped with registering meters in the delivery. Also controls may be fitted to the delivery, so that only a predetermined amount of oil can be withdrawn.

PUMP

The circulating pump shown in the diagram has the following specifications:

Size	Floor Space	Size Suction	Size Discharge	Speed R. P. M.	Gals. Per Minute	Horse-power Required
¾″	15″ x 28″	1″	¾″	160	7	½ to ¾
1″	16″ x 31″	1¼″	1″	160	11	½ to 1
1½″	20″ x 34″	2″	1½″	150	28	1 to 1½
2″	21″ x 40″	2½″	2″	140	46	1 to 2
2½″	30″ x 57″	3″	2½″	85	60	2 to 3
3″	35″ x 60″	3½″	3″	85	100	3 to 4

NOTE.—The above table is figured on the basis of a ten-foot suction and a working pressure of ten (10) pounds. Where cylinder oil and other heavy oils are to be handled, they should be kept at a temperature of at least 80° Fahr. and 20 per cent. should be deducted from the above capacities, and 20 per cent. added to the horse-power. If the horizontal suction is over 25 feet, the size of the suction should be increased one size of pipe; from 50 to 100 feet increase the size of pipe two sizes. The suction should not go over 100 feet. Do not use the ¾″ and 1″ pipes for cylinder oil, except under very favorable conditions.

CONTAMINATION AND BACTERIA

BACTERIA IN CUTTING OILS.—The oil engineer is frequently required to adjust complaints, arising from manufacturing plants, where the workmen, using cutting oils are suffering from infection on the hands and other parts of their bodies. With the advent of the employer's liability laws, this is an important factor. Infection of small cuts and scratches, due to the parts being in contact with the cutting oil, have often resulted in employees losing much time, and even in the amputation of hands and arms. It is believed that the cause of this infection is the presence of bacteria in the oil. To overcome this, some plants have added certain germicides to their oil, or sterilize the oil by the use of heat. Formaldehyde, creosote oil, carbolic acid and other germicides are among those that have been tried with the oils. In one plant one ounce of creosote oil was used to each 25 gallons of oil. At another plant 2 per cent. of carbolic acid was added to the cutting lubricant. Carbolic acid has the advantage, in that it does not affect the finished work.

Other investigators have found that cutting oils, or compounds containing cottonseed and other vegetable oils, become rancid, due to the development of certain mold and bacterial growths. It has been found however, that these bacteria are not disease-producing types.

Workmen may contaminate the oil, or emulsion, by expectorating into the fluid, or by allowing urine and other impurities to mix with it.

The Richardson-Phenix Co. made a number of tests on samples of oils taken from industrial plants. Their experiments showed, that if the oil was maintained for a period of 20 minutes at a temperature of 140° F., all harmful bacteria are destroyed.

The following typical test of a cutting oil is given:

The oil before treatment had 24 bacteria per cubic centimetre of oil. The oil was filtered before testing. The sample was a mineral-lard oil. The tests indicated that bacteria can develop in mineral-lard oil, and that they can be destroyed by heating to 140° F. for 20 minutes. The results of a test are as follows:

Temperature Fahr.	Time Heated, Minutes	Bacteria found per Cubic Centimetre
80	20	24
100	20	15
120	20	7
140	20	0

Each portion of the above test was allowed to stand for 48 hours before the counts were made. No bacteria were found in the portion that had been heated to 140° F. after standing for 48 hours at a temperature of 37° C.

It is highly recommended that large users of cutting oils, particularly where a continuous system is used, should include in the system a sterilizer. It has been found that in these central systems it is not necessary to sterilize the oil continuously. Usually about once a week is sufficient. The sterilization may be accomplished in the filter, by placing a large heating coil in the top or receiving compartment, and allowing the oil to flow over it on its way to the filtering compartments. After it has

passed into the clean-oil compartment, it is by-passed back into the top of the filter and over the heating coils again, until sterilization is complete. A separate sterilizer and cooler may be used.

OTHER CAUSES OF INFECTION.—A large oil manufacturer conducted many tests, and found that the results indicated that many cases of infection of cuts, which were blamed on the oil, were due to dirty towels, or other sources of uncleanliness.

Another source of infection may be due to verdigris, which has been formed by the slight soluble action on brass. The presence of free fatty acids in the oils used to compound with the petroleum oil may cause skin trouble.

A frequent use of soap and water should be insisted upon as the best method of preventing infection.

SKIN DISEASES AND CUTTING LUBRICANTS.—The following data were abstracted from Bulletin No. 2 of the Scientific and Industrial Research Department, Great Britain, entitled "Memorandum on Cutting Lubricants and Cooling Liquids, and on Skin Diseases Produced by Lubricants":

The skin diseases produced by lubricants are mainly in the nature of oil rashes. They may be due to two principal causes:

(*a*) *Blocking of the Glands of the Hair Follicles:* The dirt-and-oil mixture blocks the minute openings of the glands and sets up inflammation around the hairs (*Folliculitis*). Inflammation started in this manner may lead to suppuration, or abscess formation. It has been observed, that if many hairs are affected in this manner, the arm will present the appearance of a crop of red spots, with a black centre, or a yellow head, in the case of abscess formation.

(*b*) *Injury to the Skin by Metallic Particles:* The minute particles of metal, which are suspended in the cutting lubricant, may cause mechanical injury to the skin, particularly to the hands, at points where two surfaces are rubbed together, as between the fingers. Injury to the skin may also be produced on other parts of the hands and arms by wiping with a cloth or rag, while the hands and arms are coated with a film of cutting fluid in which metallic particles are suspended. The cuts or scratches produced permit the entrance of germs, and may lead to septic infection.

The best preventive against infection is to keep the machines and the workers clean. Hot water, soap and scrubbing brushes are essential equipment in factories using cutting lubricants. Workers must be instructed not to wipe their hands and arms with rags before washing off the film of cutting lubricant from their skin. Ether soap, which will dissolve the oil, has been found to be useful in preventing the inflammation of the hair follicles. Dusting the arms with a powder containing equal parts of starch and zinc oxide before commencng work prevents the action of the oil on the skin. Care must be taken in the blending of the lubricant, to prevent the formation of excess free fatty acids. The metallic particles must be frequently removed by suitable treatment. Workers whose hands have been affected by septic infection should not be allowed to work on machines, as they will infect the oil with germs and are liable to cause infection of others. Certain individuals appear to be more susceptible to the action of lubricants than others, and such persons should be removed from contact with the oil. (Abstracted through *Mechanical World*, vol. 64, No. 1661, November 1, 1918, pp. 207–208.)

CUTTING COST

CUTTING COST.—The cost of cutting metal is affected by the efficient removal of the heat generated by the cutting operation, as follows:

ANALYSIS OF COST OF CUTTING METAL

(*a*) Cost of labor
1. Operation of the machine.
2. Time required to change dull tools.
3. Time required to redress the tool.

(*b*) Cost of power to drive.
(*c*) Cost of tool steel.

THE EFFECT OF GOOD CUTTING LUBRICATION AND COOLING

(*a*) The "power cost" is decreased, by the increased speed possible with *sharp tools.*

Sharp tools are only possible when the heat of cutting is removed at a sufficiently high rate, by the lubricant, to prevent the overheating and drawing of the temper of the high carbon steel used to make these tools.

(*b*) The "cost of labor" is reduced by the reduction in the cutting time possible with *sharp tools* as outlined above. It is also reduced by the longer life of the cutting edge, due to the temper not having been drawn by the excess heat carried away by the lubricant, and the less frequent redressings required by the tool.

(*c*) The "cost of tool steel" is reduced by the longer life of tools, due to the less frequent redressings required under the operating conditions made possible by good lubrication.

PRODUCTION SPEED.—Increases in the speed of production made possible by efficient cooling or "lubrication" have been found to exceed 35 per cent., and a fair average may be taken as 25 per cent.

EFFECT OF LUBRICANT UPON POWER REQUIRED.—The economical value of a cutting lubricant was demonstrated by a large machine tool company, who were machining a large steel casting and supplying cutting compound to the two tools used. While the cutting lubricant was fed the machine operated satisfactorily. When the lubricant flow was shut off, the increased load threw off the driving belt before the tools had made a half trip around the casting. Measurements with a watt-meter showed that two and a half times the power was required to run "dry cutting" as against lubricated cutting.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH °F.	FIRE °F.	SAYBOLT VIS: @ 100° F.	SAYBOLT V.S: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

SECTION 10L
DIESEL ENGINES

TYPES OF LIQUID-FUEL ENGINES.—There are three general types of liquid-fuel engines:

(*a*) Explosion engines.
(*b*) Diesel engines.
(*c*) Sabathé engines.

In type (*a*) the fuel charge is vaporized and burns with an explosive action. In type (*b*) the fuel charge is atomized and injected directly into the engine cylinders, where it is ignited, by the heated air, compressed therein. The combustion is not of the explosive type, but is more of a slow burning. The type (*c*) engines are a combination of the types (*a*) and (*b*). The fuel is burnt at constant volume and constant pressure. They differ from Diesel engines in the method of admitting the fuel and of timing ignition, a fuel-injection valve and a special type of governor being used for these purposes. Part of the fuel is admitted before the upper dead centre of the piston is reached and burns with a constant volume. The rest of the fuel is admitted at the completion and return of the stroke, and burns at a constant pressure.

THE DIESEL ENGINE.—Diesel engines are used for stationary power purposes, marine propulsion, and to a limited state have been built for driving locomotives.

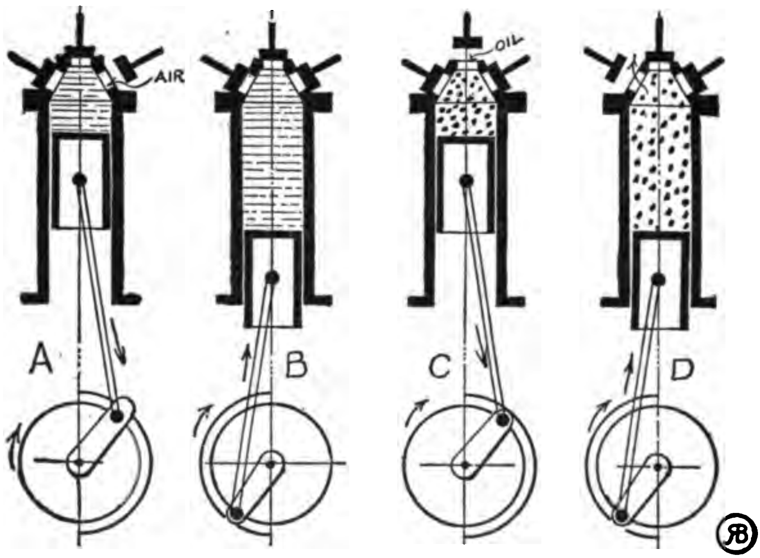
They are built to operate on the two- or the four-cycle principle. The principle of combustion in the Diesel engine embraces certain fundamental conditions not found in other internal-combustion engines.

A comparison of the operating conditions in a four-cycle explosive type of engine and a four-cycle Diesel engine will best illustrate the Diesel principle. In the explosive type of engine the moving piston imprisons a quantity of hydrocarbon vapor mixed with air between itself and the head of the cylinder and compresses it. When this compressed charge is ignited by means of a hot bulb, electric spark, or by some other means, a flame passes almost instantaneously through the entire mass of gas and air mixture, producing a highly expansive and explosive result.

FOUR-CYCLE DIESEL

FOUR-CYCLE TYPE OF DIESEL ENGINES.—The Diesel engine does not contain an explosive mixture at any time, and no explosion occurs, therefore. No carburetor or vaporizer is required.

The four strokes required to complete the cycle of events in a Diesel engine of this type are shown in outline in Fig. 1, Sec. 10L. Referring to the figure, *A* is the intake stroke, during which air is sucked into the cylinder, as the piston moves out. *B* is the compression stroke, during which the air in the cylinder is compressed to a high pressure, with a result-



1ST CYCLE INTAKE — 2ND CYCLE COMPRESSION — 3RD CYCLE WORKING STROKE — 4TH CYCLE EXHAUST

Fig. 1. Sec. 10*l*.—Cycle of operations in a four-cycle Diesel engine.

ing rise in temperature to about 1000° Fahr. As shown in *C*, fuel oil is then pumped and atomized at high pressure into the hot air, through the atomizer valve, so that a gradual combustion occurs, during a large percentage of the expansion stroke. This combustion does not produce an explosion, but is a gradual burning. Usually the spraying of the oil lasts for about 10 to 12 per cent. of the combustion stroke.

The following description of the operation of a Diesel engine operating on the four-stroke cycle, is taken from Bulletin 156, Department of the Interior, Bureau of Mines, Petroleum Technology No. 44, by Herbert Haas, and graphically explains the principles:

ENGINES HAVING A FOUR-STROKE CYCLE

Fig. 2, Sec. 10L, shows the elements of a Diesel engine having a four-stroke cycle. Important adjuncts of the engine comprise a two-stage air compressor *a*, air-injection bottle *b*, compressed-air container *c*, and fuel-oil tank *d*.

The engine piston has started on its downward travel. The air-admission valve *e* is open to the atmosphere and lets air into the engine cylinder. On its return stroke the valve *e* and all other valves are closed, so that the piston compresses the air in the cylinder to a pressure of 450 to 500 pounds per square inch. As a result the air becomes highly heated, its temperature rising to about 1000° F. when the highest pressure is reached. When the piston is at its upper dead centre, the fuel-injection valve *f* is opened and liquid fuel in a volume proportioned to the load of the engine is forced into the cylinder, where, meeting the highly heated air, it automatically ignites and burns. When an automatically regulated supply of fuel has been delivered, valve *f* closes. Under the impulse of the expanding gases, the piston moves downward, transforming the heat energy of the fuel into work. Arrived at its lower dead centre, the piston reverses its travel and begins a new upward stroke. The exhaust valve *g* being open, the piston sweeps the products of combustion before it, expelling them through this valve into the atmosphere, thus completing the four-stroke cycle. The cycle is repeated when air valve *e* opens again and the piston starts on its downward stroke.

For the sake of simplicity in describing the main features of the engine, no mention has so far been made of the important adjuncts of the fuel pump, the air compressor, and the fuel injector.

Pump *h* is under the influence of the engine governor, by which the volume of fuel delivered is proportioned to the load of the engine. The fuel oil stored in tank *d* flows by gravity to the pump, which delivers a measured quantity of oil to the fuel injector *f* during the suction stroke of the engine piston, while the needle valve of the injector is closed. The fuel injector is connected with the small air receiver *b*, in which air under a pressure of 700 to 900 pounds per square inch is stored, and air at this pressure always fills the valve chamber around the valve stem of the fuel injector.

Pump *h* in delivering its measured quantity of oil fuel to the injector must overcome the air pressure within the valve chamber. The pump is, therefore, designed to deliver the oil at a pressure of 100 to 200 pounds per square inch higher than the pressure of the air from the tank *b*, or at a pressure of 800 to 1100 pounds per square inch. The fuel oil is delivered near the bottom of the fuel injector, immediately above the needle valve. When this needle valve is opened, the injection air, which is at a pressure nearly double that of the compressed air in the engine cylinder at the completion of the compression stroke, atomizes the fuel oil and carries it into the engine cylinder. The injection air thus serves two important functions; namely, to inject the fuel into the cylinder and to subdivide it finely. The latter function is by far more important, as on its efficiency greatly depends the success with which the heavy liquid fuels are burned, but unless thoroughly atomized by highly compressed air, it would burn only partly and "after ignition" would result. * * * The two-stage

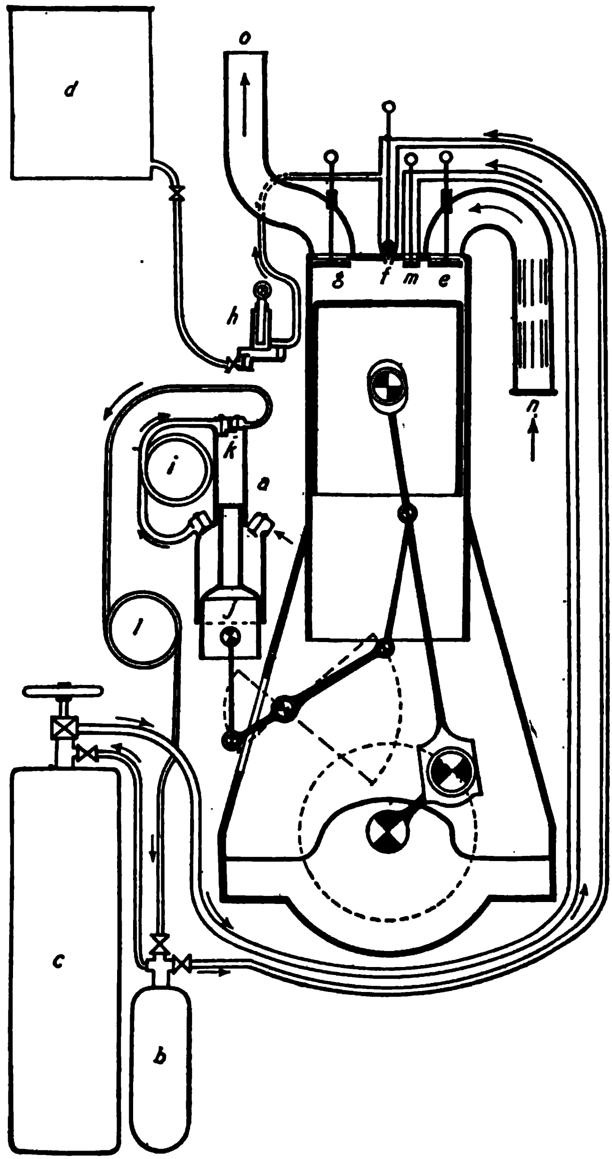


FIG. 2. SEC. 10*l*.—Diesel engine having a four stroke cycle. *a*, air compressor; *b*, injection air bottle; *c*, reserve air receiver; *d*, fuel tank; *e*, air (intake) valves; *f*, fuel injection valve; *g*, exhaust valve; *h*, fuel pump; *i*, intercooler; *j*, low-pressure cylinder; *k*, high-pressure cylinder; *l*, aftercooler; *m*, starting valve; *n*, air intake; *o*, exhaust. From Bureau U. S. Mines Bulletin No. 156.

air compressor *a* furnishes the injection air; *i* is an intercooler, to cool the air from the low-pressure cylinder *j*, to atmospheric temperature before delivering it to the high-pressure cylinder *k*; *l* is an intercooler, to deliver cold air to tanks *b* and *c*. As previously mentioned, in the compressor the atmospheric air is brought to a pressure of 700 to 1000 pounds per square inch. The air receiver *b* provides reserve air storage. Air is drawn from it whenever the engine is started and is delivered through the starting valve *m*, when the piston is at the upper dead centre, in position to receive a power impulse, air being the power medium for starting the engine. After the engine has been started, tank *c* is recharged from tank *b*, by working the air compressor at its full capacity for 15 to 20 minutes. When the desired air pressure has been restored in tank *c*, all valves leading to and from the tank are closed. The air-inlet pipe is shown at *n* and the exhaust pipe at *o*. Starting a Diesel engine from no load to full load requires 1 to 3 minutes, depending on the size and the construction of the engine.

TWO-CYCLE DIESEL

TWO-CYCLE DIESEL ENGINES.—The two-cycle type of Diesel engine, which is largely used for marine purposes, has the following cycle of events: (*a*) On the upstroke of the piston, air is compressed to about 500 pounds in the working cylinder, and, therefore is, highly heated. (*b*) Just before the end of the upstroke, an atomizer valve is opened and the fuel oil injected. Combustion immediately occurs and continues during part of the downstroke. During the first part of the stroke combustion occurs under constant pressure, while later in the stroke the work is done by expansion. (*c*) At the end of the stroke the gases are exhausted, through suitable ports now uncovered by the piston, and a blast of air is blown through the cylinder to scavenge it. The piston now starts to return upwards, the cylinder is filled with air, from the excess of scavenging air, and the operations described before are repeated.

The cylinder and cylinder heads of Diesel engines are fitted with water-cooling spaces, to prevent excessive heating. A typical high-speed, light-weight Diesel engine of the two-cycle type (marine) would have the following specifications:

Six cylinders, 600 normal brake H. P., 425 R. P. M.
Six cylinders, 1200 normal brake H. P., 370 R. P. M.

A typical heavy-weight, moderate speed, two-cycle engine would have the following specifications:

Six cylinders, 600 normal brake H. P., 275 R. P. M.
Six cylinders, 1200 normal brake H. P., 210 R. P. M.

The following description of the operation of Diesel engines of the two-stroke cycle is taken from the same bulletin of the U. S. Bureau of Mines, written by Mr. Herbert Haas, as mentioned in the description of the four-cycle Diesel engine:

Fig. 3, Sec. 10L, shows the elements of a Diesel engine with a two-stroke cycle. It differs from the four-cycle engine above described, in that it has a scavenging air pump *a* and exhaust ports *b*, arranged around the cylinder walls, covered and uncovered by the piston in its upward and downward travel, and two or more air-admission valves in the cylinder head.

The scavenging air pump *a* is double acting, and its air delivery is controlled mechanically by a piston valve. The air admission to the engine cylinder is mechanically controlled by two or more air valves *c*, in the cylinder head. The scavenging air is compressed to a pressure of 3 to 7 pounds per square inch. The air is admitted into the working cylinder as soon as the exhaust ports have been uncovered by the piston. The cylinder, full of the gaseous products of combustion, is cleared by the scavenging air, which sweeps out through the exhaust ports *b*, leaving the cylinder full of a new charge of fresh air. As the piston on its return stroke closes all cylinder valves and exhaust ports, the air is compressed in the same manner as in the engine having a four-stroke cycle, and the fuel charge is injected on the completion of the compression stroke.

During the next stroke the expanding gases give the piston its power impulse; with the opening of the exhaust ports and the discharge of the spent fuel gases, the working cycle is complete. By employing a scaveng-

ing air pump for cleaning the cylinder of its combustion products and refilling it with fresh air, a working impulse to every revolution is ob-

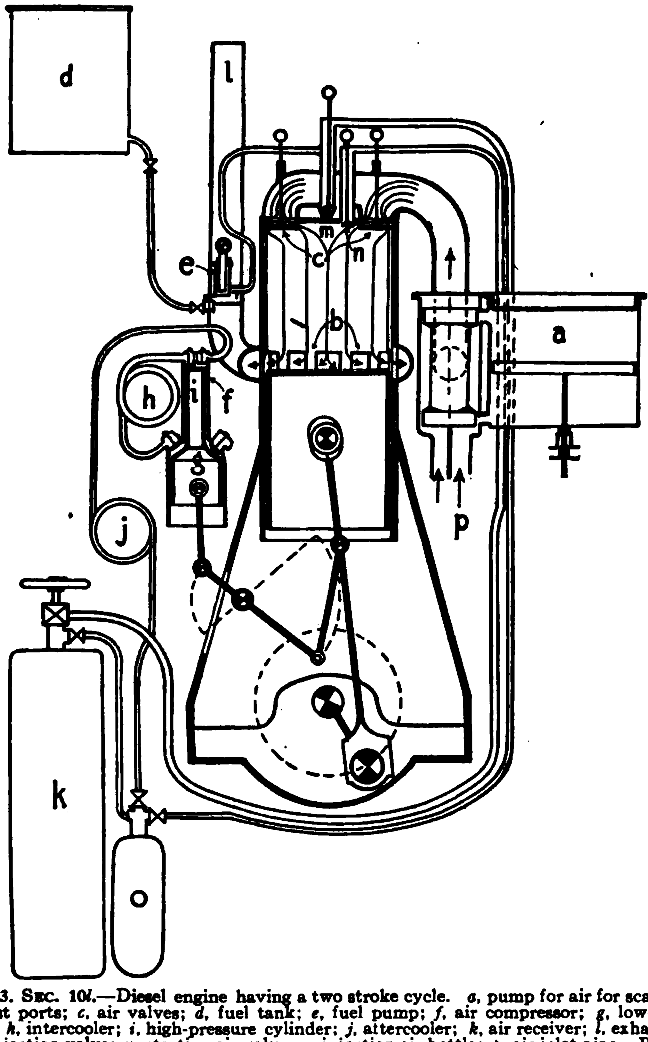


FIG. 3. SEC. 10*l*.—Diesel engine having a two stroke cycle. *a*, pump for air for scavenging; *b*, exhaust ports; *c*, air valves; *d*, fuel tank; *e*, fuel pump; *f*, air compressor; *g*, low-pressure cylinder; *h*, intercooler; *i*, high-pressure cylinder; *j*, aftercooler; *k*, air receiver; *l*, exhaust pipe; *m*, fuel injection valve; *n*, starting air valve; *o*, injection air bottle; *p*, air inlet pipe. Reprinted from U. S. Bureau of Mines Bulletin No. 156.

tained, whereas two complete revolutions to the working impulse are required in an engine having a four-stroke cycle. In Fig. 3, Sec. 10L, the air-admission valves are shown in the cylinder head of the engine. In

some later engines these scavenging air valves have been placed in the cylinder wall, opposite the exhaust ports. * * * The piston is shaped so as to direct the travel of the scavenging air in the cylinder and to arrange it in currents, that sweep the cylinder clean of the products of combustion. Thus the cylinder head is relieved of numerous air valves, which, by reason of space limitations imposed by the cylinder head, have to be of restricted area, necessitating greatly increased air velocities to effect the desired scavenging. * * *

OPERATION

STARTING.—The Diesel engine is started by admitting air to the cylinders and thus operating it as an air motor until enough momentum has been obtained to carry the pistons up against the air compression. The air-starting valves are then shut and oil is admitted to those cylinders which are ready to receive it.

The function of the fuel pumps is to receive the oil from the service tank and to force it into the atomizer. When the atomizer spindle is lifted, the injection air will force the fuel charge into the hot air in the cylinder. The compressor, which may be driven from the main shaft, or from an auxiliary, serves to keep the injection-air bottle charged with the necessary air to blow in the fuel. The compressor also serves to charge, while running, the air-starting bottles, which are used for initially starting the engine, as above described.

The compressor is usually of the multistage type, and the lubricating conditions are described for this type of compressor under the chapter on air compressors.

NOTES ON DIESEL ENGINES.—The cylinders of the average marine Diesel engine are subjected to severe expansion and contraction, due to the admission of the "starting" air to the hot cylinders when "reversing and going ahead" in manœuvring a vessel to bring her into dock. This expansion and contraction is due to the vessel having been under way for several hours or days, with her engines running in the same direction, and the cylinders and pistons have, therefore, been heated to a high degree. When the orders are rung down to the engine-room to "reverse or go ahead," the fuel oil must be shut off and the engine brought to rest. "Starting air" is then admitted to those cylinders in position to start the engine in the opposite direction. This air, which is at a pressure of about 800 to 1000 pounds per square inch for two-cycle engines and 300 to 800 pounds per square inch for four-cycle engines, is admitted to the cylinders through a valve in the head. Air at these pressures when expanded through a valve or orifice drops in temperature below the freezing point, and it can be easily appreciated that the contracting and expansive strains produced in the cylinders and pistons due to these conditions are excessive. As soon as the starting air is shut off, the compression of the air contents of the cylinders again brings the temperature up to about 1000° Fahr.

SPEEDS.—Low-speed Diesel engines will average:

Piston speeds: 600–800 feet per minute.
R. P. M.: 250–150, decreasing with engine size.
Stroke-bore ratio: Ranges from 1.3 to 1.9.

High-speed engines will average:

Piston speeds: 700–1000 feet per minute.
R. P. M.: 250–350.
Stroke-bore ratio: Ranges from 1.0 to 1.3.

COOLING WATER.—The volume of cooling water varies with the size of the engine. For four-stroke cycle engines, it will run about 2.7 to 4.0 gallons cooling water per horsepower hour. For two-stroke engines, it will average from 5 to 6 gallons per horse-power hour. Figures are based on inlet temperature of 50° Fahr. and outlet temperature of 160° Fahr.

STARTING AND INJECTION AIR

AIR COMPRESSORS, DIESEL ENGINES.—Diesel engines are usually equipped with compressors that supply air at from 800 to 1000 pounds per square inch pressure. The compressor is usually directly driven from the engine main shaft.

The compressors are of the multiple-stage type, either two or three stage. Usually there is 40 to 80 pounds compression in the first cylinder, 200 to 300 pounds in the second and 800 to 1000 in the third. The compressed air is then generally passed into steel storage bottles, or "air bottles," where the moisture may drop out and a storage provided for starting the engine.

The same conditions govern the lubrication of these compressors as outlined for these types of compressors in the section referring to this type of lubrication. (See index.)

The high temperature and pressures within the cylinders of compressors offer ideal conditions for "cracking," or decomposing, poorly refined lubricating oils. The quantity of oil fed to the cylinders should be as small as possible, care must be exercised to prevent a surplus of oil from reaching the high-compression cylinder, or there will be danger of an explosion.

Compression cylinders and intercoolers between stages must be provided with ample cooling facilities. This is necessary to avoid accidents and explosions. If the air is not sufficiently cooled and an excessive amount of cylinder lubricating oil is used, or an oil of poor flash-point, the oil vapor may form an explosive mixture in combination with the heated air, and on compression ignition may result. The air should be passed through an oil separator after leaving the last stage before being passed into the storage bottles. Cases have been recorded of a flame passing through the air pipe and into the air receiver, which happened to be filled with oil vapor and air, and a serious explosion resulted.

On some large engines more than one air compressor may be used.

For storing reserve air, under pressure, "air bottles" are used. Pressures are about 1000 pounds per square inch. There are usually two bottles for air used in starting the engine, and a smaller one for injection air. Roughly, the capacities of these storage receivers run from about 15–20 gallons per 100 H. P. for the air-injection bottle and from 60–200 gallons per 100 H. P. for the starting-air bottle.

SEMI-DIESEL ENGINES.—Since there are no satisfactory carburetors which will vaporize heavy oils without the application of heat to the fuel, and it would then not be practical to cool the fuel down between the carburetor and the engine, and the inlet air is also heated, and thus enters the cylinder in an expanded state, producing, due to its expanded condition, a reduction in the weight of the charge and a proportional decrease in power, a form of engine, which produces ignition of the fuel by injecting the fuel against the hot walls of a chamber attached to, or within, the cylinder head has been developed.

This type of engine is known as the semi-Diesel. The cycle of events of a four-cycle engine of this type are as follows: When the piston descends, the exhaust valve is closed, and the inlet valve opens, to admit air to the cylinder. In some types of these engines a certain percentage of wet steam is also admitted with the air. At the end of the stroke the inlet valve closes and the piston on the upward stroke compresses the air, or the steam and air. At a point on the upward stroke the fuel, usually, including some water or steam, is injected into the firing head, where it is impinged against a highly heated surface and vaporized. The piston continues compressing the air and its temperature increases, while this heated air is being forced into the combustion or firing head, where it mixes with the vaporized fuel, until the ignition point of the mixture is reached, when combustion takes place. The action of the steam and water mentioned above is to delay ignition until the end of the compression stroke and to reduce the formation of carbon deposit. When the combustion of the fuel occurs, the expansion of the gases, due to their temperature increases, forces the piston outward, delivering power. On the next stroke upward, the exhaust valve opens and the burnt charge is expelled.

In the two-cycle semi-Diesel the air is drawn into the crank-case and is compressed there. The engine has a port cut from the crank-case into the working cylinder, through which the compressed air passes at the end of the compression stroke. Usually in these engines water or wet steam is admitted into the inlet port, between the crank-case and the cylinder, which is picked up as the air rushes through it to the cylinder. The other operations are the same as described for the four-cycle engine.

The usual fuels used in the semi-Diesel engine are gas, distillate, alcohol, gas oils, fuel oils, crude oils, kerosene, etc. The compression averages from 100 to 250 pounds per square inch.

The semi-Diesel engine cylinders may operate under conditions of moisture, due to the injection of water or steam. and the effect of such moisture is to contaminate the oil film. A petroleum lubricating oil compounded with an acidless animal oil will give the best lubricating results.

For engines such as the Appleton, Bolinder, De La Vergne, Falk, Hornsby Ackroyd, Snow, etc., an oil of about 350–375 Vis. Say. at 100° F. (P. B.) or 500–510 (A. B.) is recommended. For engines such as the Bessemer, Foos, Muncie and Mietz and Weiss, use a compounded oil with about 5 per cent. of No. 1 lard oil. For these latter engines, see index for use of fatty acid instead of fatty oil.

FUELS

Diesel fuel oil should be free from water, since it will lower the heating value of the oil and affect the ignition. When the oil is burnt in the engine cylinder, no soot, ash or other residue should result. The exhaust should be practically clear in a well-designed engine, leaving its valves and atomizers in good condition. It is important that the oil fuel be fluid at normal temperatures, so that it will flow to the fuel pump and be easily handled. In this connection it is needless to say that the oil should be free from sediment and dirt, as otherwise the fuel valves, pumps and nozzles will clog. The oil should not contain highly volatile constituents. The oil should be subjected to a fractional distillation test. Under this test the higher the percentage of vapor removed between 200° C.–350° C. the less is the likelihood of residue occurring in the cylinder. About 5 per cent. is the maximum permissible coke content for Diesel engine fuel oil. Fractional distillation tests are important guides to the suitability of a Diesel fuel, as indicating volatility and ease of combustion of the oil, and also the fire hazard.

The ash content of the oil is generally composed of very hard mineral particles. These will cause wear in the cylinders and will also mix with the lubricating oil on the cylinder walls and bake into a crust, which will score the piston and walls. About .05 per cent. is the maximum permissible ash content.

The sediment and impurities that may occur in the oil can be largely removed by settling and straining, and by drawing the oil from the upper part of the tanks.

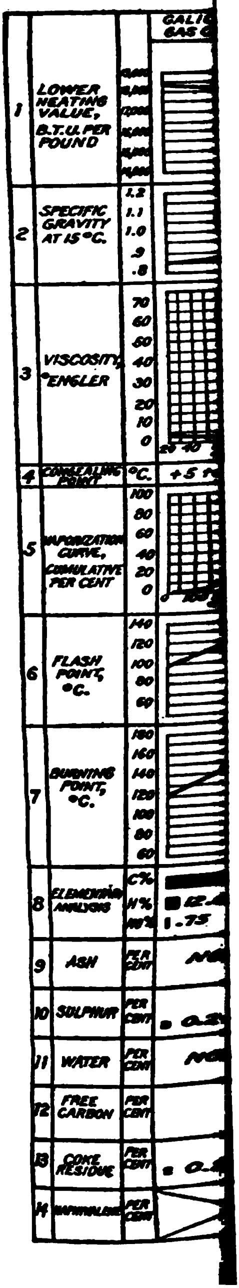
The sulphur content of the oil is usually given too much prominence. Oils, such as Mexican oils, containing as high as 5 per cent. of sulphur, have been successfully used. Where such high sulphur percentages are met, it is advisable to use cast iron instead of steel for the exhaust pipes, because, at the high temperatures found, the sulphur in the oil has little or no effect on cast iron. It is well, however, when burning oils with high sulphur content, to prevent the exhaust products of combustion from cooling down to the point where water vapor can form, as then the corrosive action of the sulphuric or sulphurous acids will occur.

Oils which are high in asphalt are objectionable, unless heated to a point where they become fluid enough to eliminate sticking of the valves.

A low flashing point increases the fire hazard of the oil. Extreme differences between the flashing point and the fire-point indicate that the oil has not been "topped," therefore, containing volatile constituents.

In general, the viscosity of the oil should be between 2.5 Engler to 4.0 Engler at 75° Centigrade.

COMPOSITION OF SOME LIQUID FUELS.—Herbert Haas, in Petroleum Technology No. 44, Bulletin 166, Department of the Interior, Bureau of Mines, "The Diesel Engine, Its Fuels and Uses," gives the following data: The composition and properties of various liquid fuels are shown in Fig. 4, Sec. 10L. * * * There is much differences in the viscosities of the different fuels. * * * There is also much variation in the temperature at which the oils evaporate, and in the degree of vaporization. * * * Only small differences between the properties of American oils and those of Mexican oils will be noted, except that the


GALI
GAS O
1
LOWER HEATING VALUE, B.T.U. PER POUND
2
SPECIFIC GRAVITY AT 15°C.
1.2
1.1
1.0
.9
.8
3
VISCOSITY, °ENGLER
70
60
50
40
30
20
10
0
20 40
4
CONGEALING POINT
°C.
+5
5
VAPORIZATION CURVE, CUMULATIVE PER CENT
100
80
60
40
20
0
6
FLASH POINT, °C.
140
120
100
80
60
7
BURNING POINT, °C.
180
160
140
120
100
80
60
8
ELEMENTARY ANALYSIS
C%
H%
N%
1.75
9
ASH
PER CENT
10
SULPHUR
PER CENT
11
WATER
PER CENT
12
FREE CARBON
PER CENT
13
COKE RESIDUE
PER CENT
14
PER CENT

latter have an appreciable sulphur content. * * * The Texas fuel oils, as represented in the figure, are excellent fuels for Diesel engines, so long as the permissible ash content is not exceeded. * * * The California fuel oils represented are unsuitable for use in Diesel engines, chiefly because of their excessive ash content and their high coke content, and their decomposition at 300° C. or at a slightly higher temperature. The oils represented in the figure are not cited as being representative of California oils generally, but as affording comparison between oils suitable for use in Diesel engines and oils that are not suitable for use. * * * The California residuum cited meets all requirements of a desirable fuel, the ash content not being excessive, although the boiling points range fairly high and the oil has to be heated for use. * * * Many Mexican crude oils, as indicated, have a low value on account of the large water and sulphur contents; likewise their ash content is frequently so high as to make them worthless for fuel for the Diesel engine. Many contain sufficient proportions of light oil to lower their flash-points and their burning points to such a degree as to make them constitute a serious fire hazard. At temperatures higher than 300° C. they decompose, leaving large proportions of coked residue.

NAVAL DIESEL ENGINE FUEL OIL.—The United States Navy specifications for Diesel engine fuel oils, for use afloat, are as follows: Flash-point not lower than 150° Fahr.—Abel or Pensky-Martin closed cup; water and sediment none or a trace; asphaltum none.

* **FUEL DATA.**—Industrial gasoline engines usually use about 0.8 pound of gasoline, or about one pint, per B. H. P.

Diesel engines average about 1/2 pound of fuel oil per B. H. P. hour for a 100 H. P. engine.

Triple expansion steam engines, in good shape, will average 1 1/2 to 1 3/4 pounds of coal per I. H. P. hour.

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* NOTE. See index for other data.

DIESEL ENGINE EFFICIENCY

EFFICIENCY.—The mechanical efficiency of a Diesel engine is the effective power remaining after the power consumed by the moving parts of the engine and by frictional resistance has been deducted from the indicated power. The air compressor, which furnishes the air for injection, is usually driven from the engine, and requires from 7 to 15 per cent. of the total power of the engine to drive it.

The mechanical efficiency of two-cycle engines is lower than four-cycle engines, as, in addition to the air compressor, the scavenging pump must be driven. About 80 per cent. is the usual mechanical efficiency for low-speed engines, of four-cycle type, of medium and large horse-powers. Exclusive of the air compressor, the efficiency is about 85 to 90 per cent. For two-cycle engines the mechanical efficiency is about 68 to 70 per cent.

The thermal efficiency of a Diesel engine is the ratio of the horse-power developed, measured in equivalent heat units, to the total heat units consumed in the fuel. There are two kinds of thermal efficiency, based upon whether the indicated horse-power or the brake horse-power is used to obtain the efficiency. Since 778 foot pounds of work is the mechanical equivalent of heat, and one horse-power is 550 foot pounds per second, then thermal efficiency is:

$$E_t = \frac{550 \times 60 \times 60}{778} \times \frac{(\text{I. H. P.}) \text{ or } (\text{B. H. P.})}{(F H)}$$

$$E_t = \frac{2545}{(F H)}$$

Where F is the number of pounds of fuel consumed in one hour and H is the heating value of the fuel per pound in British Thermal Heat Units.

The Indicated Thermal Efficiency (based on I. H. P.) of four-cycle engines of the Diesel type runs from about 45 per cent. at full load to 47 per cent. at half load. The Delivered Thermal Efficiency (based on B. H. P.) is about 37 per cent. at full load. Two-cycle engines will run about 10 to 15 per cent. lower.

DIESEL LUBRICATION

METHODS OF LUBRICATING THE DIESEL ENGINE.—The original method for introducing oil to the cylinder was by a single tube leading to a belt, which encircled the liner. Small holes in this belt distributed the oil. This method is unsatisfactory, due to clogging of the passages, and the belt must be frequently cleaned out with kerosene.

Another more recent method is to drill four holes and tap tubes into them leading through the water-jacket. These tubes are fed by a common pipe, which is equipped with a back-pressure valve and leads to the oil pump. Sometimes each tube is equipped with a separate feed pipe, which leads to a separate outlet at the oil-pump lubricator. This provides adjustment for each cylinder. The feed pump for supplying the oil should be placed below the level of the cylinder tubes, to avoid drainage of the feed pipes when the engine is shut down, and a resulting lack of lubrication for an appreciable time after the engine is restarted. These feed pipes should always be kept full. Frequently test out the check valves to discover any clogging. Pistons may be " seized," if the tubes which are placed in the drilled holes, as above described, expand. Often it occurs, that when the tubes are tapped into the water-jacket, instead of into the liner, they will expand when highly heated, and by sticking slightly out into the cylinder cause the piston to bind.

Some top bearings depend for their supply of oil upon the scraping action of the upper part of the piston, collecting enough oil from the liner walls to fill their needs.

For the medium- and high-speed Diesel engines a forced-feed system is best. The top end bearings should be fed through a passage up through the centre of the connecting rod. This passage should be equipped with a check valve to prevent drainage, as before described.

Another method for bringing the oil to these bearings is to provide slots in the piston, which pass over the leads from the oil-supply pipes, and holes are provided leading from the slots through the piston to a centre hole in the gudgeon pin. Several holes lead from this gudgeon hole to the outer bearing surface. The slots on the piston scrape oil from the liners. For a six inch (6") pin, the hole in the centre should be 1 1/4 inches in diameter. Two or more holes, drilled at 30° to the vertical centre line, are best for feeding out the oil to the pin bearing.

A good point for examining the action of the oil upon the metal of the engine is to watch the valves of the air bottles for any sign of corrosion or scouring.

In those engines where the shift and connecting rods are not drilled for forced-feed lubrication, each crank may be provided with a centrifugal oil ring, that is intended to supply oil to the crank-pins, the crank-pins being drilled so that the drilled ducts take the oil from the rings and deliver it to the pin brasses. Oil rings are usually cut on the shaft to hold the oil in the main bearings and to lead it to the crank-pit oil reservoirs. The crank-pin for driving the air compressor is usually part of the main shaft. It is lubricated in the same manner as described for the other crank-pins.

There is a helical gear mounted on the main shaft, meshing with

another gear, for driving the governor shaft. These gears are lubricated by an oil bath.

Pressure lubrication for the main bearings is common.

Engines equipped with centrifugal oiling rings have a separate oil supply for the piston pin.

Marine Diesel engines are usually lubricated by a forced-feed system. The lubricating system serves the cylinders, wrist-pins, crank bearings, and main bearings. Usually two grades of oil are used, one for the cylinders and one for the bearings, although on marine engines one oil is sometimes used for both.

The selection of the lubricant is dependent upon the type of the engine. Gravity systems are used on large open-frame engines. On small sizes, especially with enclosed crankcases, a mechanical oiler with leads to the separate bearings, or a forced-feed system, is used. The objection to gravity feed or mechanical oilers is the large number of pipes that require attention. Forced-feed systems provide a surplus of oil, but with marine engines must be watched for salt water leaks. With open-frame engines care must be taken to prevent cylinder oil from dripping into the crankcase. This is particularly true with trunk piston engines, with the closed crankcases, as the oil fouls with finely divided carbon particles, turns black and thickens, tending to clog the oil passages. Centrifugal separation is very satisfactory for clarifying the oil and removing a good percentage of the carbon.

For ordinary working conditions, stationary and marine, an oil of 245–275 Vis. Say. at 100° F. (P. B.), or 350–375 Vis. Say. at 100° F. (A. B.) is used. For severe working conditions oils of 350–375 (P. B.), or 600–650 (A. B.) Vis. Say. at 100° Fahr. give good results. They must be non-emulsifying oils for circulating or forced feed.

Where the feeds are separate, use an oil of about 375–400 Vis. at 100° F., for the main, crank pin, piston pin, and cam shaft bearings and for the oil baths into which the cams and cam shaft dip. For the cylinders use an oil of 465–500 Vis. Say. at 100° F. (blend of filtered low cold test cylinder stock and a neutral, for P. B. oils), or 675–750 Vis. Say. at 100° Fahr. for A. B. oils.

For cooling the piston several methods are used. The most common are salt water, fresh water or lubricating oil circulation. Oil has the disadvantage of low specific heat, being about 0.4 that of water, and consequently much more oil must be circulated to carry off the same amount of heat. The advantage of oil is, that in case of leakage occurring within the crankcase, the oil mixes with the other oil without damage. The larger sized engines generally employ water cooling. As an illustration of oil cooling with one system, the oil is carried to the main bearings, thence through the hollow crankshaft to the crankpin bearings, and up connecting-rod passages to the wristpins, and from there through passages to the hollow head. It then passes back to a low point of the piston, from which it is allowed to drain directly to the crankpit.

The atomizer valves are actuated by cams, push rods, lifter rods, and valve levers. The cams are usually encased in iron boxes, which should be kept filled with a good quality cup grease, No. 2 or No. 3 consistency.

The cam shafts in four-, six- or eight-cylinder engines are necessarily long and are supported by bearings between each cylinder. These bear-

ings are equipped with grease cups, and No. 3 consistency cup grease will give the best results.

The oil used to lubricate these engines is subjected to a very severe test, much more severe than is met with in an internal-combustion engine of the explosive type. The oil should have a reasonably low cold test, not over 10° Fahr. pour.

In certain engines special arrangements, such as step pistons, are used for air starting, in which cases the starting air is never admitted to the working cylinders, but acts upon the step pistons, which in turn become scavenging pumps for the adjacent cylinders when the engine is running on fuel.

The oil used for cylinder lubrication of the Diesel engine must be capable of remaining stable at comparatively high temperatures. The oil must be also free from asphaltum and resinous products, and should be entirely soluble in 86° gasoline.

The lubricating oil used for cylinder lubrication may be made gummy or otherwise impaired if the fuel oil used runs high in sulphur, due to the formation of sulphur dioxide or treoxide, which has an undetermined action on the lubricating film.

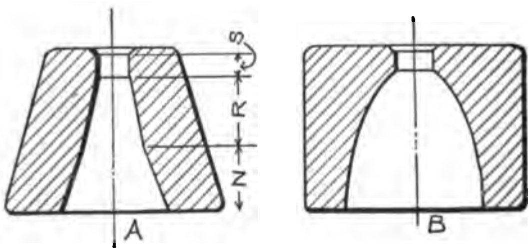
SECTION 10m

METAL DRAWING OPERATIONS

WIRE DRAWING.—Wire drawing is the process of reducing the cross-section of a metal bar, by drawing it through a tapering hole, whereby the metal is compressed and elongated.

The purpose of wire drawing may be to produce a smoothly finished product of more accurate size than can be obtained by rolling.

Fig. 1, Sec. 10m, shows a cross-section of wire drawing dies, the section being taken through one of the holes. For high-carbon wire the die shown at *A* would be used, and for copper wire the die *B* is used. The large tapering portion *N* is used as a receptacle into which the rod carries the lubricating material, which is caught between the wedge-shaped sides of the die, and carried along into the real working section at *R*. When



STEEL **COPPER**

FIG. 1. SEC. 10m.—Sections through steel and copper wire drawing dies.

passing through *R*, the real compression and metal flow occurs. The neck *S* merely serves to take up the wear on the die and becomes shorter in length as the life of the die deteriorates.

Dies for high-carbon wire have long working sections, as is shown at *R*, in die *A*, while copper wire drawing dies are shaped as is shown by die *B*.

PROCESS OF WIRE DRAWING.—The "rod bundle" is thrown on the "wire-drawing bench" and given a tapering point. This point is entered into the die, which is held in a metal box. Lubricating grease, or powdered soap, fills the box, and as the rod passes through the die box, the lubricating medium is carried into the hole and interposes a protecting film between the wire and the die. This prevents metallic contact, which would quickly ruin the wire and the die.

After the "tongs" have pulled through sufficient of the wire, its end is attached to the "drum," or "block," which is revolved, and the "drawing" operation starts.

FORM 1 HP

SECTION No. ____

RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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The "drum spindles" are driven by bevel gears and several block units are mounted on a frame or "wire bench."

Lime Coat.—An important factor in the lubrication of drawing iron wire is the lime coat. When the rods first come to the wire mill, they are covered with scale. This scale must be removed, as its hard surface would destroy the die hole.

To accomplish the removal of the scale, the rods are immersed in hot, diluted sulphuric acid, which dissolves and loosens it. A stream of water is then run on the rod bundles and the loosened scale is washed off. The rods are next immersed in a hot lime-water vat and a thin lime coating adheres to them. This coating is believed by wire manufacturers to have great value in aiding the lubrication of the metal as it is drawn through the dies. It is not known whether the lime combines with the grease to aid it in lubrication, or whether the roughened surfaces merely aid in carrying an increased quantity of the lubricant into the die. The lime-coated rods are baked before being taken to the wire benches.

Sull.—If water is sprayed on the rods after cleaning in the acid, a soft, slippery coating of iron oxide is formed upon their surfaces. This coating is covered by the lime coating and acts as an additional aid to the lubrication of the rod during the drawing operation.

Redrawing.—Wire may be subjected to several drawings through "reducing dies" before the final resulting size is obtained.

Lubrication.—A typical "*drawing oil*" would have these general tests:

(*a*) 24 to 25 gravity.
(*b*) 400 to 420 open flash.
(*c*) 170 to 180 Vis. at 100° Fahr.
(*d*) 30 to 40 cloud.
(*e*) 50 per cent. cottonseed oil.

"*Wire-drawing grease*" is usually made in two consistencies, No. 2 and No. 3, and is a good quality petroleum, lime grease.

In dry wire drawing, which may be used for sizes down to No. 18, tallow or soapstone is used as a lubricant.

"Petroleum Grease" is sometimes used for this purpose.

OTHER DRAWING OPERATIONS.—For drawing soft steel, a compound consisting of a soap with a large fatty-oil content was used. This is mixed with water to give various consistencies according to the kind of work to be done. Whale-oil soap is also used to some extent, but under severe conditions the animal fat in the above-described soap gives better results.

When drawing metal which must afterwards be enameled, a drawing compound that is freely soluble in water must be used, so that after drawing, the metal surfaces can be cleaned to take the enamel. If a lime-soap grease is used, the lime soap, being soluble in water, would not permit obtaining a clean surface.

Extra winter strained lard oil is used in some plants as a drawing lubricant. In one plant, 107-pound I. C. tin was drawn with lard oil successfully, but when soft steel, .015 thick was substituted, the dies stuck and tore the metal when lard oil was used.

When the drawing compound does not give satisfactory lubrication, the die scratches the work and quickly becomes rough. It must then

be emeried out and then shrunk back to size, thus causing loss of time and running the danger of cracking the die.

The clearance formula used in many shops for the punch and the die is as follows:

$$\text{Clearance for brass and soft steel equals } \frac{\text{Thickness of stock}}{10}.$$

$$\text{Clearance for hard-rolled steel equals } \frac{\text{Thickness of stock}}{8}.$$

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SECTION 10n

DRY CLEANING

DRY-CLEANING EQUIPMENT

GENERAL.—Fig. 1, Sec. 10n, shows a conventional dry-cleaning plant. The gasoline is settled in the cone-bottomed tanks, so that it can be used over again after each washing of cloth.

The large cylindrical machine is the washer, and the soiled cloth

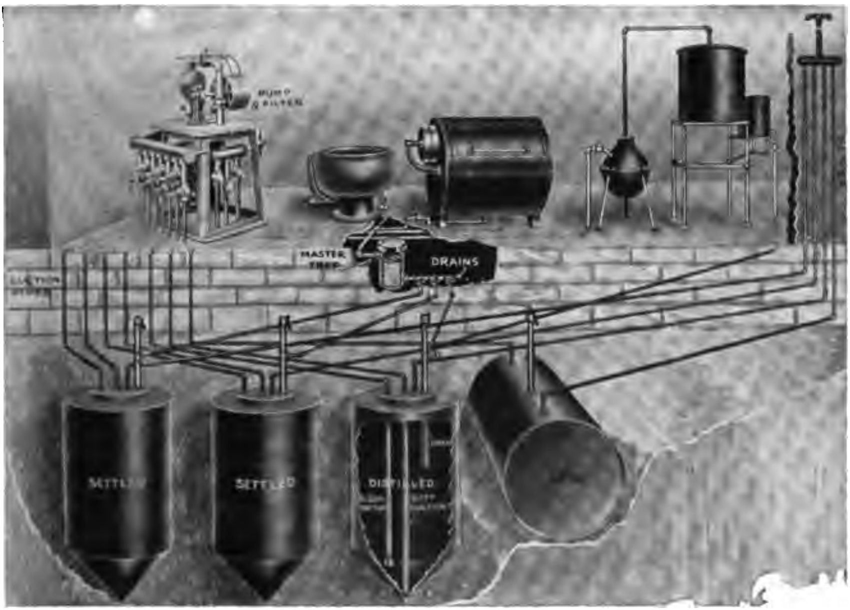

FIG. 1. SEC. 10n.—A conventional dry cleaning plant as designed by the Milwaukee Tank Works.

is placed in it. Gasoline is then drawn by means of a pump from the tank desired and put into the washer, the clothes are tumbled about in the gasoline, after which the gasoline is drawn off and given about 24 hours to settle before reusing. The dirt and muck settle to the bottom of the cones in the tanks, from which it is drawn off and discharged into the still, where it is distilled and then drained into the tank desired.

Fig. 2, Sec. 10n, shows a hand-operated dry-cleaning system.

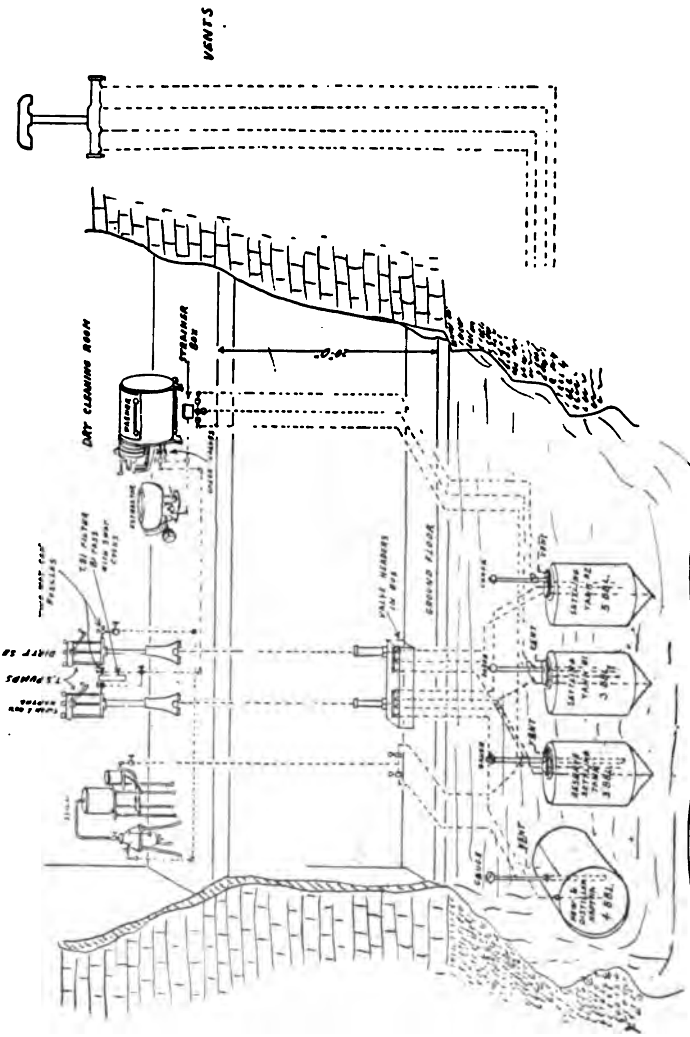

FIG. 2. SEC. 10N.—Hand operated dry cleaning system as designed by Gilbert & Barker Mfg. Co.

FORM 1 HP

SECTION No.______

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SECTION 10p

ELECTRIC CARS

LUBRICATION OF ELECTRIC CARS

The lubricating requirements of the principal bearings found in electric cars separate these bearings into three classes. These classes have been named by the manufacturers of electric cars as follows: Motor Axle Bearings, Journal Bearings, and Armature Bearings.

MOTOR-AXLE BEARINGS.—The bearings on which the motor is supported on the axle are called Motor-Axle Bearings. These bearings are fitted with caps, so arranged that the opening, in which the oil waste is packed, is on the side of the bearing. The waste has merely to rub against the axle to convey sufficient oil for lubrication. The electric current to drive the motors is brought through by way of the wheels and axles and passed through the motor-axle bearings to the motor. This electric current has a tendency to heat these bearings, and this heat being in addition to the heat of friction, produced by the weight of the motor and the rotation of the axle, often causes these bearings to run hot.

Motor-axle bearings wear very rapidly. Often a wide space is worn between the box and the axle, and, owing to the bearing being near to the ground, considerable grit and dirt is picked up from the track and finds its way into the bearings.

There are four factors to be considered when studying the lubrication of these bearings: 1. The difficulty of getting oil to feed through waste in a horizontal position. 2. The temperature produced in the bearing by the electric current when the motor is under full load. 3. The metal used in the bearing and the load per square inch on the axle when the car is loaded to capacity and on the heaviest grades. 4. The condition of the bearings with reference to wear.

JOURNAL BEARINGS.—The bearings which support the weight of the car on the axles are called the Journal Bearings. These bearings are fitted with a shoe or block, which rests only upon the upper part of the axle, so that the lower part and a section of each side of the axle is exposed to oil waste, which is packed in the journal boxes.

JOURNAL BOXES.—The boxes which enclose the journal bearings are called Journal Boxes and are closed by a cap. This cap should fit snugly to prevent grit and dirt from entering the bearing and causing heating and hot boxes.

PACKING OF JOURNAL BOXES.—At the back of the Journal Box, where the axle passed through, there is a large opening. Journal Boxes require careful packing to prevent the oil from the waste travelling back along the axle and dropping to the track. In order to prevent this loss of oil, a plaited piece of waste, as large as can be forced between the axle and box casing, should be packed against the extreme back of the box before any oily waste is put in. This piece of waste should be

plaited before being soaked in oil. The bearings should be packed loosely, yet snugly, with a spungent waste.

The waste used should remain elastic after it has been soaked with oil. On the sides of the bearing the waste should be packed to just below the centre line of the journal, and at the ends, the waste should come to only about 1/2 inch above the bottom of the flange, on the end of the journal.

PREPARING WASTE. OILING.—Packing waste should be soaked with oil and then drained until at a temperature of about 100° Fahr. there will be no oil droppings when the waste is suspended in the air.

DRAINING.—The draining of the waste after soaking is a very important factor in reducing the amount of oil used. The waste should be spread out in layers, not more than 2 inches thick, on the draining screen. Never pile the waste on the screen, as the oil draining from the upper layers will merely resoak the partially drained waste below it.

OIL.—Car oil should have enough viscosity to keep the waste well saturated without dropping at a temperature of at least 100° Fahr. For summer use the oil must have more viscosity than is required in winter. The oil should have a flash test of about 380° to 400° Fahr. and a cold test in winter of at least 5° Fahr.

ARMATURE BEARINGS.—Armature bearings are those bearings in the frame of the motor which carry the armature. These bearings are equipped with oil pockets for oil waste and are located directly above the shaft. There is a cap which fits over these pockets to exclude dirt and grit. Armature bearings should be packed tightly at each end of the pocket and loosely in the middle.

PACKING THE JOURNAL BEARINGS.—When a car is in constant use, the journal-bearing packing should be examined every third day, and the waste in the centre turned at each examination, to prevent the surface of the waste next to the shaft from becoming glazed and thus feeding no oil to the bearing. The waste at the end of the pockets should be rope-twisted, so that the middle waste will be kept separated and make it easier to change. This rope-twisted waste should also be changed at frequent intervals.

WINTER MOTOR TROUBLES.—One of the causes for failures of car motors has been found to be faulty conditions of the drain holes at the bottom of the motor. Often carelessness in oiling without gauging and the subsequent flooding of the bearings has caused the collection of oil inside the motor near the drain holes. This oil mixed with dirt and blocked up the drain holes. This causes water to collect in the motor and the lower field coils were soaked, causing them to break down, particularly when the water froze.

LUBRICATION OF MOTOR GEARS AND PINIONS.—It is quite common to find a radical difference between the life of the same grades of gears and pinions on cars having the same equipments. This difference is largely due to the efficiency of lubrication.

The greatest factor affecting gear lubrication is the grit or abrasive substances which accumulate in the gear pan. This grit mixes with the lubricant and acts as an abrasive coating to both the pinion and gear. Samples that have been removed from the gear pan have shown the lubricant to consist of as high as 26 per cent. of grit.

This sand and grit enters between the gear hub and gear pan in the form of street dust, wheel wash and brake-shoe dust. If the lower half of the pan is exposed to dust when it is lying in the pit, it will furnish another source of grit entrance to the gears.

Another great cause of pinion and gear wear is due to the fact that the armature shaft bearing nearest to the pinion becomes worn on the side farthest from the axle, while the bearing on the opposite side wears on the side near the axle. This allows the pinion teeth to mesh at an angle to the gear teeth, and causes the ends of the teeth next to the motor to perform the largest amount of the work. Some of the latest types of motors are provided with dust guards, which enclose the axles between the bearing housings, and prevent the entrance of dust to the linings of these bearings.

LUBRICANTS FOR GEARS AND PINIONS.—Many greases offered for lubricating the gears are filled with various substances, such as resin, talc, pine tar, etc. These substances are not lubricants; also they tend to separate out in use.

The grease used should have high adhesive qualities, to permit forming a protective coating on the teeth. It should not dry up or lose weight in service, and should be light enough in body to permit it flowing into the path of the gears as they dip into the gear pan, so as to prevent the teeth cutting a path or track and then running dry. It is well to have the grease or compound light enough to allow any grit and dirt to settle to the bottom of the pan when the lubricant is at rest.

A light-bodied petroleum-pitch pinion grease will give the best results.

ELECTRIC RAILWAY LUBRICATING CONTRACTS.—Many electric railways have contracts with the oil companies to furnish lubrication for their cars at a definite rate per car-mile. The oil company furnishes all of the oil required from time to time during the year, and charges for it at a definite list price per gallon. At the end of the year the total car-miles are multiplied by the guaranteed cost, and if the total payments made to the oil company during the year exceed this result, the difference is refunded by the oil company, while if the total paid to the oil company is below this result, the oil company simply retains the full amount received during the year. This system of making lubricating contracts on a mileage basis has some advantages, but the purchasing agent and master mechanic can obtain better results by buying lubricants by the gallon and supervising their application. Usually a saving in the cost per car-mile can be shown by the gallonage method over a mileage contract if a careful record is kept of the amounts of oil used. Purchasing agents should remember that mileage contracts are more or less of a gamble on the part of the oil company. There is always a safe margin figured in the contract cost to cover any loss to the oil company which may be due to the personal efficiency factor of the railroad employees, with reference to the application and use of the lubricants supplied and over which the oil company has no control; as well as any special conditions which cannot be foreseen at the time the contract is made.

Any large oil consumer, such as an electric railway, can buy oil under a yearly contract at very low prices per gallon, and since the railway company has first-hand control over its employees using the oil, there are great possibilities of effecting a considerable reduction in the cost of lubrication per car-mile if careful supervision is maintained.

SECTION 10q
ELECTRIC CRANES

ELECTRIC CRANE LUBRICATION

The main points requiring lubrication on an electric crane are the gears and pinions and the motor.

The gears are usually highly polished cut gears. For the fast crane these gears run at about 600 R. P. M. The crane goes ahead and stops with a jerk, reverses and goes ahead again, so that the back as well as the front of the teeth receive the same wear.

On a typical 5-ton electric crane the pinion and gears had the following specifications: The pinion was 6 inches in diameter by 2 1/4 inches across. The teeth were 3/4-inch deep, with a 1-inch circular pitch. The gears were 16 inches in diameter, with 50 teeth, and were attached directly to the driving wheels.

For the gears and pinions, a petroleum pinion grease of medium consistency, applied with a brush, will give good results. These greases are usually made by cutting back a petroleum residuum with a light-bodied oil, and can be bought in several consistencies.

The bearings of the pinion rod should be equipped with grease cups and should be supplied with a medium grade of cup grease.

The motors require a light-bodied neutral oil for use in their ring-fed bearings.

The brake devices for electric cranes are of various designs, but the most general one requiring attention is that constructed in the form of washers and known as the washer-load brakes. This type of brake has a device in a case for holding the lubricant for the bands and washers. An oil of 125 Vis. (P. B.) or 150 Vis. (A. B.) will usually give the desired results. The oil must remain fluid at all times, so as to find its way between the washers, and for that reason the temperature conditions must be considered, and for those conditions where the surrounding air is cold, a zero-test oil is recommended.

Where the gears are encased in a metal case, a semi-fluid lubricant of 3/4 consistency is recommended.

The crane cable should be lubricated with a cable lubricant. One method is for a man to stand on the trolley and apply the grease as the cable is wound up. Another method is to wind up the cable and the top half is greased; the bottom half is then greased after the drum has made a half revolution to bring the ungreased cable into an " up " position.

FORM 1 HP

SECTION No.____

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FORM 1 HB

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SECTION 10r

ELECTRIC MOTORS AND DYNAMOS

MOTORS AND DYNAMOS

Dynamos and motors are usually equipped with self-oiling bearings of the ring- or chain-feed types. These bearings are described in the section on Bearing Lubrication.

OVERHEATING OF BEARINGS.—Overheating of the bearings of dynamos is sometimes caused by unequal magnetic fields between the armature and the poles. This may cause an unequal wear in the bearing and result in causing the shaft to drop down out of alignment.

If the dynamo or motor is equipped with a belt and pulley, excessive bearing pressures may be produced by an unnecessarily tight belt.

For direct-connected dynamos, overheating of the bearings should immediately result in an inspection of the alignment of the outboard bearing. Stray currents have also been known to have produced trouble in dynamo bearings.

LUBRICATING OIL.—The same principles govern the selection of an oil for use in the self-oiling bearings of electric machines as is used in the selection of an oil for high-speed engines having splash-feed bearings. The body of the oil will, of course, vary with the size of the machine. The viscosity should be as low as possible. The oil should have only sufficient viscosity to permit the rings to carry enough of it up to the bearings to provide ample oil for lubrication, and should be sufficiently free-flowing to permit the free delivery of the oil from the rings to the journal. The viscosity of the oil must also be low enough to permit of its free circulation and cooling when it is in the reservoir.

The reservoirs should be of ample size, so as to permit the oil to have sufficient time to give up the heat brought from the bearing before it is again carried up by the rings. Very often these reservoirs are entirely too small, and the engineer, in trying to overcome this defect, uses an oil having an unnecessarily high viscosity. Trouble will be periodically experienced from this condition, and it will pay the engineer to enlarge the reservoir. This can often be done by tapping a capped pipe into the lower part of the reservoir; this extra capacity and increased cooling area will usually bring about the desired results.

NOTES.—It is a good plan to occasionally draw the oil out of the reservoir and allow it to stand for a few hours in a closed bucket, so that any dirt will settle to the bottom, and the oil can then be replaced in the reservoir.

After an oil has been in a reservoir in active use for some time, it will become darker in color, due largely to metallic wear.

Dynamos and motors that are exposed to cold weather should be supplied with a low cold-test oil.

If the viscosity of the oil is too high, it will not spread quickly over the surfaces of the bearing, and in starting up after standing for some time, the oil will have mostly drained back into the reservoir, and will not spread fast enough to prevent excessive friction and heat being generated in the bearing.

Care must be taken to maintain a fairly constant level of oil in the reservoir, so that the rings will be sufficiently immersed.

The action of the rings of hot-running bearings should be examined, to determine whether there is any jumping or shaking. Both of these actions are produced by the rings having sharp edges and badly worn grooves.

SECTION 10s

ELEVATORS

ELEVATOR LUBRICATION

In considering the lubrication of the various parts of passenger and freight elevators, the proper oiling of all of the parts having moving contact must be included, regardless as to whether they are in frequent motion or only occasionally move. This is particularly true of those parts composing the governor mechanism of the safety drum under the car. Water, which may seep through a non-waterproof floor when the car is being cleaned, is apt to cause rust and corrosion of the safety drum and mechanism unless it is kept properly oiled or covered with a rust-protecting grease.

HYDRAULIC ELEVATORS.—The internal parts and wearing surfaces of hydraulic-elevator systems are usually lubricated by mixing or emulsifying the lubricant with the water in the tanks, and then trusting to the passage of the water to distribute sufficient of the lubricant over the contact surfaces. There are several oils and compounds on the market for this purpose. A satisfactory emulsion-forming oil would have the following approximate specifications:

(*a*) It should mix thoroughly with water in all proportions, to form a stable emulsion.

(*b*) It should be in liquid form and composed of not less than 20 to 30 per cent. of a soluble alkali soap and the remainder of a mineral oil, compounded with a small quantity of resin.

(*c*) The oil must be free from mineral acids and free alkali.

(*d*) The oil must show no corrosion on a polished surface that is kept in contact with it for at least two weeks.

THE PLUNGERS.—The plungers of elevators, plunger pumps, etc., require that close attention be paid to their lubrication. If allowed to become dry, they will cut and wear out the packing quickly, in addition to the increased friction. scratching and scoring of the surfaces. A good graphited grease will produce excellent results on these surfaces, as this grease will withstand the washing effect of condensed moisture, which often is present on the surfaces of the plungers. A good grease for this purpose will have the following specifications: It should soften without flowing at 110° Fahr.; should consist of about one part amorphous graphite and two parts mineral cup grease.

MOTOR AND TRACTION BEARING LUBRICANTS.—For the bearings of the electric motor, which are usually equipped with ring oilers, a light, neutral oil of about 150 Vis. at 100° Fahr. is recommended. For the bearings of gearless traction machines, a slightly heavier oil is required such as a non-emulsifying oil of 180 Vis. at 100° Fahr. (P. B.) or 200 Vis. at 100° Fahr. (A. B.).

WIRE CABLES.—The wear of wire cables is both external and

internal, the former being due to abrasion and chafing against the pulleys, sheaves, etc., and the latter due to the rubbing of the wires of the strands upon one another in bending under load. The chief trouble from wire

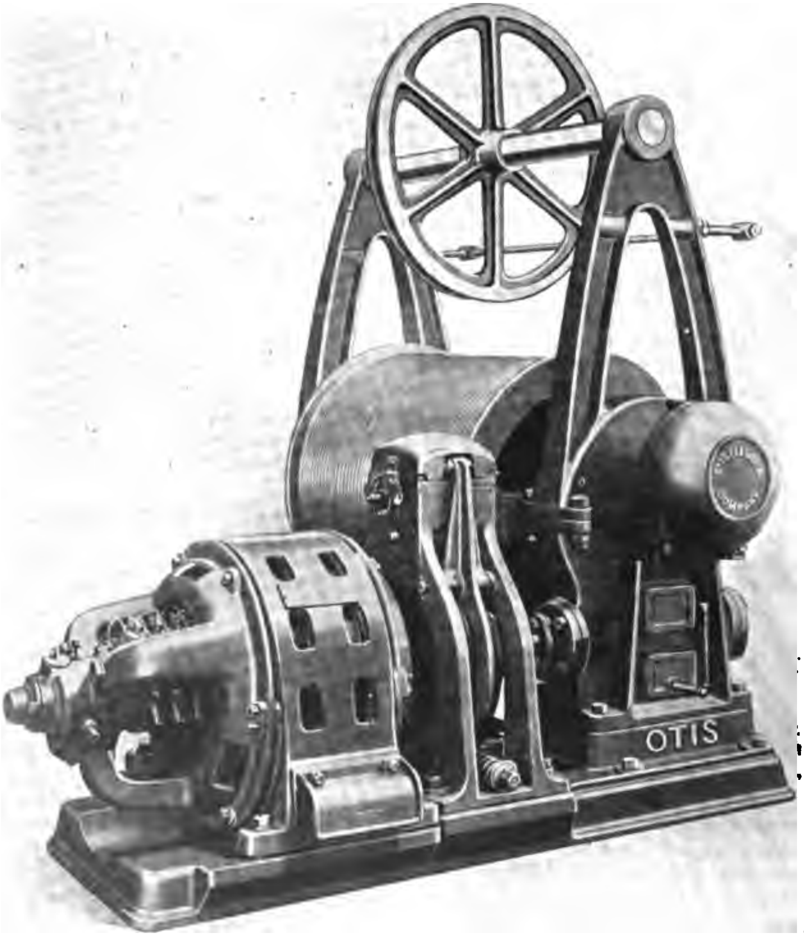

Fig. 1. Sec. 10s.—Winding drum machine for elevator.

cables is caused by rust. The cable must be internally as well as externally lubricated. The lubricant should protect the outside wires from wear and rust, and should also penetrate the cable, to reduce the friction between the internal surfaces of the wires.

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Many lubricants have been tried for this purpose with varying success. A petroleum-pitch product, having a consistency of a very heavy cylinder oil, will stick to the cable and resist any peeling action or chafing effect, as well as lubricate the interior wires, by penetrating between the strands.

There are several oilers on the market for elevator cables. It is claimed that oil will penetrate quickly between the strands and will not leave a sticky, dust-collecting coat on the cable. A heavy engine oil of 350 to 375 Vis. at 100° Fahr. (P. B.) or 450 to 500 Vis. at 100° Fahr. (A. B.) will give the best results with these oilers.

FIG. 2. SEC. 10s.—Elevator lubricator for grease. (Courtesy, Industrial Oil Equipment Co.)

For the compression cups of sheaves, and all bearings fitted with grease cups, use a good grade of mineral cup grease of No. 3 body.

ELEVATOR GUIDES.—In practice, a car for freight service will weigh about the same as its lifting capacity. Thus a car with 10,000 pounds lifting capacity will weigh about 5 tons. It is not possible to suspend a car and operate it so that it will maintain a central position exactly. It will lean off centre to one side or the other, and usually offers three contact surfaces between the rail shoes and the rails. Thus it is of importance to insure good lubrication between these surfaces.

The best form of lubricant for elevator guides is a high-quality cup grease of about 3 1/2 to 4 consistency.

There are several good elevator lubricators on the market. Fig. 2, Sec. 10s, shows a form of grease lubricator, which has the features of feeding the grease to the three contact surfaces. It also is designed to give a constant feed, regardless of whether the cup is full or partly empty, through the feed-regulating valve which balances exit orifice against spring pressure. The contact feeds have no felt pads to become glazed, and are held to the rails by means of springs, thus taking up the swaying of the car. A test is on record with this type of lubricator as follows: On a 10 1/4 hours per day service, a distance travelled of 4,235,944 feet (264 feet 4 inches per round trip), 1.7 ounces of grease (for one rail) was used as against 5/8 pint of oil on the opposite rail of the same car; this consumption being equivalent to 1.25 pounds of grease per year (two rails) and 7 1/2 pints of oil (two rails) per year.

WORM-DRIVE ELEVATORS.—Castor oil has been largely used as a lubricant for the worms of worm drives. The smooth running of a worm-drive elevator depends largely upon the efficiency of lubrication. The lubricant used for worm-gear lubrication must have a body sufficiently heavy to form and maintain a film on the worm and gear when the elevator is loaded to capacity and running at maximum speed; it must also be able to resist the squeezing-out action of the worm and gear. The worm-spindle stuffing-box is usually packed with square-braided flax or hemp

packing, and the lubricant should keep this soft and pliable. Sometimes the packing contains rubber, and petroleum lubricants will tend to cause this packing to fall to pieces and leak. In some installations the worm and gear are enclosed in a gear case and are lubricated by a bath of gear lubricant. In these cases the worm-thrust bearings are lubricated by the worm-gear lubricant. These bearings are ball, roller or thrust collars, and the lubricant used must not tend to cause any damage to the highly polished surfaces of these bearings, and should not contain graphite, resin, wax, mica, asbestos or any similar substance.

One of the most common forms of complaint concerning elevator worm-gear lubricants is that the lubricant is carried up by the gear and works its way out along the shaft of the drum. In this case, if the winding machine is at the top of the shaft, the lubricant will drip down on freight or passengers in the car. The best form of lubricant next to castor oil is a semi-fluid grease or gear lubricant made with a heavy cylinder stock.

Fig. 1, Sec. 10s, shows an elevator-winding drum machine made by the Otis Elevator Co.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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SECTION 10t

EXTRUSION OF METALS

PROCESS.—The process consists essentially in pressing an ingot, or block of metal, through a form or die, so that a bar or a pipe of the cross-section of the die is produced.

There are three general classes: (*a*) The extrusion of pipe, wire, sheets and bars from ingots or blocks of metal, which must be preheated in order to give them plasticity to pass through the dies. (*b*) The extrusion of shells and short tubes from blanks, which do not have to be preheated. (This differs little from press work.) (*c*) The making of collapsible tubes from tin and lead, such as are used for toothpaste, vaseline, etc.

The usual machine required with the preheated process is of the three- or four-rod, horizontal, hydraulic type, with a production of 50,000 to 80,000 pounds of extruded shapes per day. Pressures up to 100,000 pounds per square inch are exerted upon the heated billets. Small gears, rachet wheels, gear racks, padlock hasps, etc., are extruded in long bars, which are afterward sawed to the required thickness.

Lead and tin can be extruded at comparatively low temperatures (250° Fahr.). Copper and its alloys, containing any considerable percentage of copper, require temperatures of from 1500° Fahr. to 1800° Fahr., depending upon the copper content. The billets are preheated to these temperatures, and should be so maintained during the extrusion.

OIL REQUIREMENTS.—Ingots of brass and similar alloys are cast in billet moulds. These are dressed with a mixture of fish oil and powdered charcoal before the hot metal is poured into them. The billets are then preheated and placed in the billet containers of the machine. This container is designed to keep the billet hot. In order to avoid trouble from the billets sticking to the container walls, various schemes have been developed. In one type the billets are made smaller than the container bore diameter. The encircling space is filled with a liquid which is non-compressible, and thus keeps the billet from coming into contact with the container walls as the ram forces the ingot through the die.

It has been found that a greater force must be used with this form of container, because, due to the fact that no lubricant has as yet been evolved which will withstand the high temperatures met with. Soap water gives the best results with aluminum and lard oil with copper and copper alloys.

PLATE AND DIE OIL.—When punching plates and for cutting washers, etc., from scrap plates, with stamping machines, a heavy oil is swabbed over the plate and on the dies, to furnish some lubrication for the cutting operation.

Usually a black lubricating oil, such as summer black oil, is used for this purpose. (See index for Summer Black Oil.)

SECTION 10u
FLOUR MILLS

FLOUR MILLING MACHINERY

MILL LUBRICATION.—The most important points of lubrication in a flour mill are the journals of the rolls used in the grinding machines. These rolls weigh from 90 pounds, for a 6-inch x 6-inch roll, to about 2540 pounds, for an 18-inch x 30-inch roll. Roller mills are referred to as "two pair high," or "three pair high," depending upon the number of pairs of rolls in the machine.

The rolls of each pair are driven at different relative speeds, and thus each pair of rolls has one roll driven from the "fast side" and one roll driven from the "slow side." The rolls may be driven by belts on both the slow side and the fast side, or belt drive may be used for the fast side and gear drive for the slow, or differential, side. The rolls are made with corrugated or with smooth surfaces, depending upon the class of work they are designed to do.

ROLL DATA.—The rolls of typical roller mills will have the following approximate diameters and speeds:

Two Pair High Roller Mills (Ring Oil Bearings)

Size of rolls	Horsepower	Speed of top fast roll	Diameter of journal
6″ x 12″	3 to 5	600	2 1/8″
9″ x 14″	5 to 8	500	2 1/4″
9″ x 30″	12 to 18	500	2 5/8″
10″ x 36″	20 to 25	450	3 3/8″

Two Pair High Ball Bearing Roller Mills *

Size of rolls	Horsepower	Speed of top fast roll	Diameter of journal
6″ x 12″	2 to 3	600	2 1/16″
9″ x 30″	7 to 11	500	2 5/8″

CONVEYORS.—Flat belt and cast-iron spiral conveyors are widely used in flour mills. "Carriers," for grain-conveying belts, are spaced about 5 or 6 feet apart, and for "return rollers," at about 8 to 10 feet apart. These carriers should receive periodic attention and their oil cups be kept filled with a good red engine oil, having a viscosity of about 275° at 100° Fahr. (P. B.) or 350° at 100° Fahr (A. B.). The speed at which the belt conveyors run is, on the average, about 750 feet per minute.

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* NOTE. For the three high roller mills, the roll dimensions and speeds are about the same; the capacities and required driving horse-power are, of course, higher.

The rolls are run under a pressure of about 2000 pounds to 5000 pounds per journal.

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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Standard spiral steel conveyors will have the following general specifications:

Outside diameter of conveyor	Length between bearings (centre)	Average speed per minute
6″	10′-0″	200
9″	10′-0″	170
14″	12′-0″	140
18″	12′-0″	120

PACKERS.—Barrel and sack packers usually contain a pair of bevel gears. These machines are run at about 200 R. P. M. and are lubricated by hand oiling.

EXHAUST FANS.—These fans are designed for taking the hot air from the rolls and for other purposes. The speeds of the machines will usually range from 500 to 800 R. P. M. for wooden fans and from 300 to 550 R. P. M. for cast-iron exhaust fans, depending upon the size of the fan and the pressure desired. Oil cups are provided on the bearings.

DUST COLLECTORS.—There is considerable dust in the air in flour mills. Exhaust fans and cyclone collectors are used to free the air of dust, and these machines, which are run at high speeds, should be freely lubricated with a medium-bodied red oil of about 175 Vis. at 100° Fahr. (P. B.) or 205° to 210° Vis. at 100° Fahr. (A. B.).

NOTES.—The dust in flour mills is excessive and the bearings are rarely free of a coating of it. The bearings are mostly hand fed, and for this reason are frequently neglected for too long a period of time. Large savings in power can be effected in the average flour mill by scientific lubrication.

For the quick-running gears of the roller mills, a medium-bodied gear grease (see index) should be used, or a light-bodied pinion grease will give satisfactory results, provided its consistency is very low.

Many flour mills are equipped with rope drives. The ropes should be lubricated with a good penetrating grease, since the wear of driving rope is both external and internal. The internal wear of the rope is due to the fibres moving over each other under pressure, in bending on the sheaves, and the external wear is due to the slipping and wedging effect, occurring on the sheaves. The size of the pulleys has an important effect upon the wear of the rope: the larger the sheaves the less the internal movement of the fibres, and the lower the internal friction.

Under normal conditions, cotton ropes do not require as much lubrication as Manila ropes, because their fibres are not as tough.. Avoid placing an excess of grease upon the ropes, or the dust in the mill will soon collect upon them. Manila rope is almost universally used for transmission of power. Grease for use on Manila roping should be of fairly soft consistency and should be free of any excess of alkali or resin.

Some mills use fibre grease for general lubrication.

SECTION 10v

FORGING

DROP FORGING.—The first element in forging is heat, which is required to reduce the metal to a condition that is sufficiently plastic to yield and assume the desired shapes. The second element in forging is force. This force may be applied by compression, concussion, or it may be a combination of both of these.

It is essential when heating metal for forging that the metal be given sufficient time in the furnace to permit the heat to penetrate to the core, so that when it is subjected to the forging operation the effect of the pressure will penetrate to the core, or centre, and insure uniform structure of the steel in the forging.

DIE SWABBING.—Drop-forge concerns sometimes use tallow, straight for die swabbing, and it is undoubtedly a very satisfactory product, but expensive. Some plants use as a die swab black oil mixed with graphite. Others use a dry-flaked graphite. In some shops No. 3 or No. 4 grease mixed with graphite is used.

When forging small parts, it is necessary to use a die swab to prevent the dies from sticking; also in work such as crank-shafts, where accuracy is a factor. The swabbing medium is swabbed on the die with a swab, and the hot metal is then placed onto the die and the hammer is released.

A swabbing product, for use with steam hammers, must be capable of operating under high heat conditions without pouring or running off. It must leave the dies clean and effect a release after the tremendous pressure which is brought to bear, at the time of contact.

The swabbing medium is expected to form gases and release the hot metal from the die instantaneously. This action is only secured in tallow or a satisfactory tallow substitute. If this is not effected, the contact weight is so heavy that the dies become soaked and will probably crack.

The cost of dies is high and diemakers are highly paid men, so that very careful study should be made of the die-swabbing situation.

Some drop-hammer concerns use nothing but water on their dies. It is supposed by these operators that the steam that is generated by this water under the heat conditions present acts as a die cleanser, but there is certainly no preserving action effected on the die.

The best practice is to use a product that will expand under contact with the hot metal under pressure. They clean the dies with dry steam, which is blown onto them under high pressure.

A tallow substitute that is successful for this purpose has the following formula:

50 per cent. special dark petroleum grease.
20 per cent. No. 1 tallow, or prime tallow.
15 per cent. wax tailings.
15 per cent. De Gras.

FORM 1 HP

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FORM 1 HD

SPECIFICATIONS

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SECTION 10w
HEAT TREATMENT OF STEEL

STEEL AND IRON

DEFINITIONS.—All ferrous metals contain the elements carbon, iron, phosphorus, manganese, sulphur, and silicon in varying amounts.

It is by classifying the different metals, according to what proportion of each of these elements they contain, that determines the various products which we know as steel, wrought iron, etc.

* Alloy steels are those which involve the elements chromium, vanadium, manganese (over about 7 per cent.), nickel, or tungsten. When the amount of these rare metals is specified by the maker, they are known as special steels.

HIGH-SPEED STEEL.—Ferrous metals, which contain iron, carbon, phosphorus, manganese, and sulphur, the carbon content being .60 to .80, and in addition vanadium, tungsten, molydeum, or cobalt, all or in part, are classified as high-speed steel.

It is also customary to include chrome and nickel with the last four-named metals. They are alloy tool steels.

SELF-HARDENING STEEL.—High-speed steel is sometimes called self-hardening steel, but on the other hand, a simple steel which is high in manganese and which contains 2 per cent. nickel, or sometimes tungsten, may be a self-hardening steel.

WROUGHT IRON.—This is a simple steel, which is very low in carbon content. Usually the carbon content is under 0.15 per cent. It may be high in sulphur and phosphorus. It is also called malleable iron.

DEAD SOFT STEEL.—Ranges in carbon from 0.08 to 0.18, and is used for pipe, chain, and welding purposes; also for case hardening, pressing and stamping.

STRUCTURAL OR SOFT MEDIUM STEEL.—Ranges from 0.15 to 0.25 carbon, and is used for structural plates and shapes, boiler flange steel, bolts, drop forgings, etc.

MEDIUM STEEL.—This ranges 0.20–0.36 carbon, and is used for shafting, drop forgings, auto parts, etc.

MEDIUM HARD STEEL.—Carbon ranges 0.35–0.60, and is used for large forgings, locomotive axles, rails, etc.

HARD STEEL.—Carbon ranges 0.60–0.85, and is used for locomotive tires, hammers, crow-bars, rails, etc.

SPRING STEEL.—Carbon ranges 0.85–1.15, and is used for railway springs, general shop tools, rock drills, hot and cold chisels, etc.

CAST STEEL.—This product may have the same characteristics as the other steels from a chemical standpoint, but, due to the fact that it is cast, it is, therefore, without grain fibre and will not resist shocks. It does not have the internal strength of rolled steel.

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* NOTE. Also defined as steels which owe their properties chiefly to the presence of an element or elements other than carbon. If the carbon is over about 2 per cent., they are termed ferro-alloys.

STEEL DATA.—Steel is an alloy, the principal constituents of which are iron and carbon. The chief hardening component of steel is its carbon content.

Steel is not a simple substance like silver, since steel is composed of a number of individual substances.

When steel has been slowly cooled from a high temperature, there is in the steel "ferrite," "cementite," and "pearlite," in varying relative proportions, depending upon the chemical composition of the steel.

"Ferrite" is practically iron, free from carbon in solid solution.

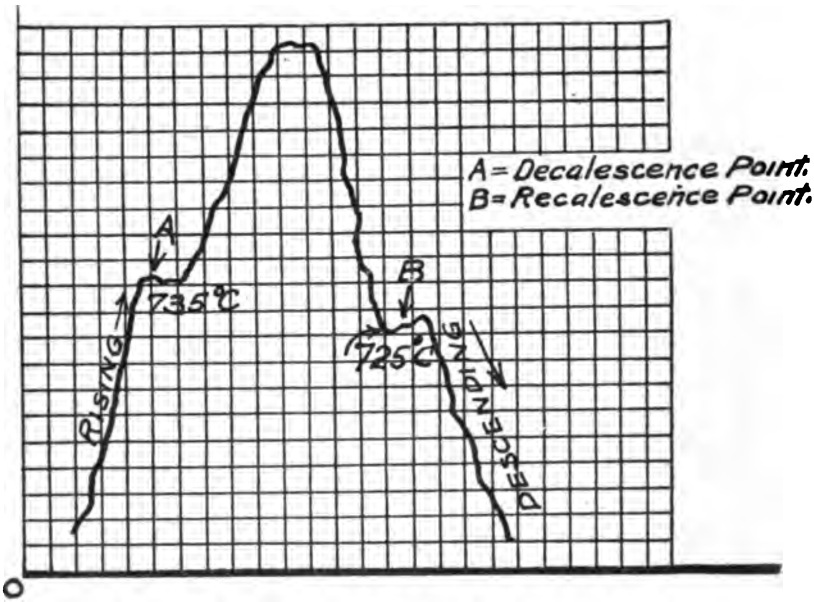

Fig. 1. Sec. 10w.—Curve obtained by a recording pyrometer, showing "critical points."

"Cementite" is an iron carbide, consisting of 93.3 per cent. of iron and 6.7 per cent. of carbon, Fe_3C.

"Pearlite" is a mechanical mixture of "cementite" and "ferrite," which contains about 0.9 per cent. of carbon.

At normal temperatures the steel carries its carbon as pearlite carbon. When it is heated to a certain temperature the pearlite carbon changes to cementite carbon, or hardening carbon, and then if slowly allowed to cool, the cementite changes back to pearlite.

On heating, the temperature at which this change occurs is known as the "decalescence point," and on cooling the point is known as the "recalescence point." These points can be definitely determined with the aid of a pyrometer, or recording thermometer, which measures the temperature of the steel, because when heating steel, a point is reached

(decalescence) where the temperature of the steel stays stationary while the steel continues to absorb heat, and *vice versa*. On cooling, a point is reached (recalescence), where the steel gives out heat without lowering in temperature. A curve obtained with a recording pyrometer, which shows the decalescence and recalescence points, is shown in Fig. 1, Sec. 10w. (These points are sometimes referred to as Ac. 1 and Ar. 1.)

There is another method of determining the critical points; namely, by means of a magnet. Steel above the decalescence point is non-magnetic. The decalescence point varies with the carbon content, and it is important, in that it indicates the correct hardening temperature of the steel.

The recalescence point, when the steel is cooled slowly, is usually about 90° to 220° Fahr. lower than the decalescence point.

CARBON STEELS.—As an illustration of the effect of carbon on the properties of steel, *Machinery* (October, 1909, and January, 1910), gives the following data: In a "ten-point" carbon steel (one in which there is present but 0.01 per cent. of carbon), the tensile strength is very nearly 25 per cent. greater than that of pure iron. Adding more carbon causes the tensile strength to rise approximately at the rate of 2.5 per cent. for each 0.01 per cent. of carbon added. Carbon steels may be divided into three classes, according to the carbon proportions which they have. The first class, comprising the "unsaturated steels," has a carbon content lower than 0.89 per cent.; the second class, comprising the "saturated steels," has a carbon content exactly 0.89 per cent.; and the third class, comprising the "supersaturated steels," has a carbon content higher than 0.89 per cent.

CRITICAL POINTS.—When ordinary carbon steels are heated, they begin to soften at about 390° Fahr., and continue softening through a range of about 390° Fahr. At about 700° Fahr. the hardness of the steel has about all gone.

The temperature at which the change occurs between hard and soft is referred to as the "critical temperature, or point." The higher the carbon percentage the lower the critical temperature.

HEAT TREATMENT

HEAT TREATMENT.—The factor which controls all heat treatment is temperature.

Heat treatment may be described as the change, or series of changes, in temperature; and also the rate of change from one temperature to another, which is brought about to secure certain sought-for properties in a metal or an alloy.

Suitable equipment, such as furnaces, quenching baths, pyrometers, etc., should have ample capacities to handle the desired output without overtaxing. The heating and cooling operations must be so directed that each piece will be as nearly as possible at the same temperature throughout the section from outside to centre, and from end to end. All pieces in the lot treated should be subject to the same conditions, to obtain uniformity of results.

Special heat treatments are classified as hardening, tempering, annealing, and grain refinement. In each of these operations the existing properties of the steel are changed, to produce some permanent condition.

HARDENING

HARDENING.—Hardening steel consists in heating the steel to obtain the formation of the hard constituents in the steel, and then rapidly cooling the steel, by quenching it in some liquid, such as water or oil to hold the steel in that condition.*

The steel is heated to a point slightly above its "decalescence point," so that it is uniformly heated and also to allow for some drop in temperature while the piece is being transferred to the quenching bath, thus insuring the proper quenching temperature.

The steel must be uniformly heated if uniform results are to be obtained. Ununiform heating may result in "hardening cracks." The steel may be heated in a furnace, or various heating mediums may be used. Lead baths and salt baths are sometimes used for certain kinds of work. They are intended to give uniformity to the heating and to prevent oxidation, and in some cases to give a bright surfaced metal after hardening.

The heating of steel for hardening should be governed by the following rules:

(*a*) Slow heating, so that all parts of the piece will be heated to the the same temperature.

(*b*) Projections and cutting edges must be heated more rapidly than the rest of the piece.

The maximum hardness is obtained for any steel when it is quenched with the maximum rapidity in a quenching medium which possesses the greatest heat conductivity. The degree of hardness obtainable with different grades of steel is governed by the particular composition of the steel, as well as by the rate of cooling. The rate of cooling is dependent upon the size of the piece quenched and on the nature of the quenching medium. The resulting degree of hardness varies directly with the heat-absorbing efficiency of the bath and its conductivity, and, indirectly, or inversely, it is a function of the time required to cool the steel to ordinary temperatures.

Steel should be hardened at as low a temperature as possible. There is a definite temperature for each kind of steel, above which it must be heated to harden at all.

Each kind of steel requires a distinct temperature to which it should be heated for hardening. For carbon steels, this temperature is about 1300° F. to 1650° F., while for high-speed steels it is about 1800° to 2350° Fahr. Usually results can be obtained with alloy steels under slower cooling than is required for carbon steels. Thus, instead of quenching a hot tool in oil or water, it can be exposed to a current of air.

It should be remembered that quenching can only retain in the steel the characteristics which have been developed by heating. It is not possible, therefore, to correct incorrect heating by subsequent quenching. For this reason it is necessary for the oil engineer to appreciate the value of investigation into the complete story of the hardening operation, which involves both heating and cooling.

When the steel has been correctly hardened, it will show no trace of its original structure.

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* NOTE. Hardening may also be by the cold, mechanical working method.

Thus, when the hardening constituents have been formed in the steel by heating, the quenching medium is then depended upon to hold the steel in that condition by cooling it rapidly. Furthermore, it is evident that as far as the heating operation is concerned, the changes in the structure of the steel are much the same for both hardening or annealing, and that the final results obtained are different, due to the rate of cooling through the critical temperature.

DETERMINING THE PROPER HARDENING TEMPERATURES OF HIGH CARBON STEELS.—Fig. 2, Sec. 10w, shows a

Fig. 2. Sec. 10*w*.—Decalescent outfit.

decalescence outfit, consisting of a furnace, rheostat, high resistance recording pyrometer, with decalescence couple and flexible leads.

The method of operation is as follows: Take from the steel a sample test piece of one of the following dimensions: 1/2-inch in diameter, 1 inch long, drilled and counterbored to receive the twisted and welded ends of the couple; or a sample may consist of two pieces approximately 3/4-inch thick and 1 inch long, which may be clamped by means of small bolts to make firm contact with the twisted and welded ends of the couple. The furnace is then allowed to reach a temperature of 1600° to 1650° Fahr., and is then held constant at that temperature by means of

a rheostat control. The sample test piece is then inserted into the heated chamber and the sample gradually is heated, causing a deflection of the pyrometer pointer. The pointer gradually moves across the chart of the recording pyrometer, leaving a record. When the decalescence is reached, a flattened part of the curve will indicate it, and the temperature may not increase, as shown by the curve, for several minutes. This is the proper quenching temperature for the steel. However, in practice, the steel is removed from the heating furnace at a temperature slightly above the decalescence temperature, to allow for a drop while transferring it to the quenching bath. It is customary to allow for a 10° to 25° drop, depending upon the size of the piece.

Some operators prefer to start the furnace up cold with the test piece in it, instead as above described, as they obtain a more pronounced deflection in the curve by this method.

TESTING THE HARDNESS OF METALS — BRINELL METHOD.—The best practical method for testing or measuring the hardness of metals is the indentation method which has been adopted by Brinell.

In this method a hardened steel ball is pressed into the smooth surface of the metal under observation by means of a fixed load, so that an indentation is made. This indentation is measured by the aid of a microscope.

The dimensions thus obtained are used as the basis for calculating the hardness of the metal. If the number of kilograms making up the load is divided by the area of the spherical surface of the indentation, this area being expressed in square millimeters, a value is obtained which represents the pressure exerted per square millimeter of ball impression. This value, or number, is taken as a measure of the hardness, and is called the "Brinell number."

To convert kilograms per square millimeter to pounds per square inch, a factor of 1422.3 may be used.

Many plants standardize their heat-treatment product by taking the hardness of each piece treated.

It has been observed that the Brinell hardness numbers follow closely the tensile strength of the same types of steel, whether they are heat-treated or untreated.

For practical purposes, the tensile strength of a test piece can be assumed to be one-third of the hardness number, in metric units, or the hardness number can be multiplied by the coefficient of 0.346 as a uniform constant, and the result obtained will be the ultimate tensile strength of the material in kilograms per square millimeter, which can be changed to pounds per square inch by the above factor.

Fig. 3, Sec. 10w, shows a view of a hydraulic testing machine. It consists of a hydraulic press, a hand pump and a pressure gauge, with an attachment for controlling the weights. A microscope especially constructed to read the ball-test impressions is furnished. It has a reflector, which furnishes a strong illumination for the test piece, and with the aid of a small steel rule fitted in the bottom of the cylinder, the exact diameter of the impression may be read to 1/10 of a millimeter.

The machine is furnished with several 10-millimeter steel balls. The test piece should be perfectly plain and even on the spot where the ball

impression is to be made. The piece to be tested is placed upon the press table and brought into contact with the ball. The valve is then closed, and by means of a hand pump a pressure of 3000 kilograms (6614 pounds)

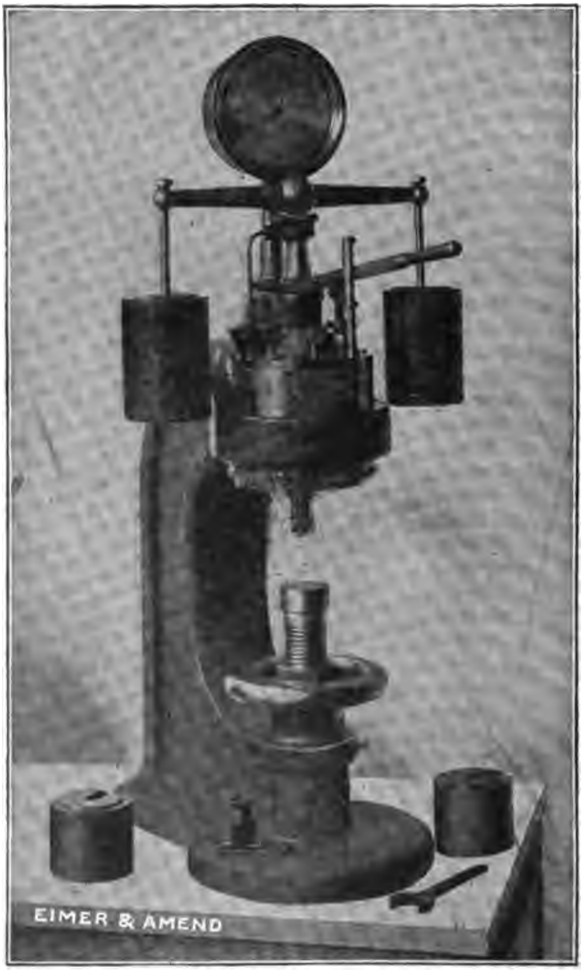


FIG. 3. SEC. 10*w*.—Hardness tester.

is put on the ball. Iron and steel are subjected to this pressure for 15 seconds, and softer material for about 30 seconds. After this time the valve is opened and the pressure is released. The diameter of the impression is then measured with the microscope, and the corresponding hardness number is looked for in the table furnished with machine.

HARDNESS—SCLEROSCOPE PRINCIPLE.—The principle of the scleroscope consists in dropping a small hammer from a fixed height onto the surface of the material to be tested. The hammer, after striking,

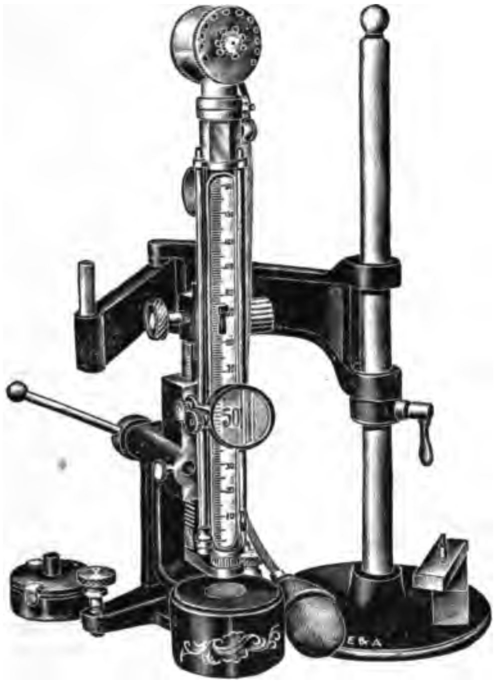


FIG. 4. SEC. 10w.—Scleroscope.

rebounds to variable heights, depending upon the hardness of the material under test.

Fig. 4, Sec. 10w, shows a scleroscope.

QUENCHING

PHYSICAL PROPERTIES OF QUENCHING OILS.—The physical properties of a liquid which have a bearing upon its value as a quenching medium are:

(*a*) *Heat Conductivity.*—This is a measure of the rapidity with which it will exchange heat between the different parts of the bath.

(*b*) *Latent Heat.*—When a liquid passes from the liquid to the gaseous state, its temperature remains stationary at a certain temperature point. In order to make the change continue, a quantity of heat must be added, which does not raise the temperature of the liquid, but is lost in causing it to assume the gaseous, or vapor, state. This is called the latent heat.

(*c*) *Specific Heat.*—This is the thermal capacity of the oil. It is the quantity of heat required to raise the temperature of a certain weight of the oil 1 degree in temperature. It is a measure of the amount of heat that can be absorbed by a volume of the oil when raising its temperature through a given number of degrees of temperature.

(*d*) *The amount of charred material in the oils* which adhere to the metal that is quenched.

(*e*) *The Volatility.*—This factor controls the movement of the liquid and is a feature in regards to rapid cooling.

(*f*) *The Rate of Oxidation of the Oil.*—This is a factor which affects the physical properties of the oil and is a measure of the waste.

A good quenching medium should possess high specific heat, as low viscosity as is practical, high heat conductivity, high latent heat, and should be capable of being maintained at a comparatively low temperature.

Quenching oil must have no moisture content. Drawing and tempering oils should have good flash tests to avoid excess vapors being freed and igniting. For gears, crank-shafts, connecting rods, springs, and other pieces requiring steel of maximum strength and minimum weight, there was first used such alloys as chromium, nickel, vanadium, tungsten and others, and then heat-treated steels came into use. These require the use of mineral, or fixed, oils for quenching and tempering.

The cooling rate of mineral oil is estimated to be about 23 per cent. that of water. Water cools steel too fast and air too slow. When steel is heated to approximately 1280° Fahr., a change occurs in the molecular structure of the iron and carbon, in which the component parts of the steel are joined into what is called a solid solution. Steel cooled in water has its outer shell cooled first, thus leaving the inside, or core, still molten, and as the core cools it dialates and may warp the piece.

The flashing point of tempering oil is not as important as the flashing point of quenching oil, due to the fact that the steel is introduced into the tempering oil at atmospheric temperature for the bath, and the rise in temperature of the oil, due to the heat taken from the steel, is offset by cooling it through cooling coils.

The shape and size of the steel and its composition must be considered in selecting the quenching medium. Some plants quench in water at 90° Fahr. until the steel has reached approximately 600° to 700° Fahr., and then transfer the work to the draw furnace to be tempered. Heating

up the water is objectionable, because of the generation of steam. The strains and stresses are produced while the steel is passing from the critical temperature (about 1200° Fahr.) to the atmospheric temperature.

A mixture of oil and water has been used, but does not seem to have proven successful, due to the heat from the forgings destroying the emulsifying properties of the oil and resulting separation.

Quenching properly means the rapid extraction of heat, and is commonly used in the same sense as hardening; yet manganese steel or high nickel steel, for example, when plunged into water from a yellow heat is quenched and toughened, but not hardened. This is contradictory to the ordinary "quenching hardening," and is called "water toughening."

The temperature and nature of the liquid determine the rate of cooling, and also the temperature to which the object may be cooled. There is apparently no peculiar virtue or individual difference possessed by any one medium over another, except what pertains to the respective heat-extraction ability and parallel rate of cooling. It is the rate of cooling that is responsible for the results.

NOTE. "Crocodile skin" is the name given to the appearance of the piece, resulting from oil or grease on the surface, which has not entirely burned off during heating, or gives a deposit producing a coloration.

"Double hardening" means quenching the piece twice, generally in oil or water, and is particularly applicable to casehardened pieces, having a low carbon core with a high critical point and a high carbon case with a much lower critical point. A preliminary high temperature quenching refines the core and is followed by a quenching from a lower temperature.

QUENCHING SPEEDS

QUENCHING SPEEDS OF OILS.—Some of the oils for quenching and tempering purposes are: Fish oil, cottonseed oil, whale oil, lard oil, linseed oil, petroleum oil, and mineral oil compounded with fish or cottonseed oils, or, lard oils.

The quenching speed is in direct proportion to the heat conductivity of the oils.

The main factor that governs the selection of a quenching oil or medium is the rapidity with which the oil permits the transference of heat from the hot steel to the oil. The specific heat indicates the heat absorption power of the oil. The "*conductivity*" of the oil indicates its capacity for transferring this heat to the cooler parts of the bath. The viscosity of the oil is a factor influencing the movement of the oil, and is, therefore, a factor affecting the uniformity of its cooling action. The volatility, or tendency to change from a liquid state to a gaseous state, is important, in that the vapor thus formed collects around the piece and prevents the quick removal of the heat from the steel.

The rate at which a hot body radiates heat and a cooler body absorbs this heat depends, for one thing, upon their relative temperatures. It is, therefore, evident that when a quenching bath becomes heated beyond a reasonable limit, the heat transference, and thusly the quenching speed, is altered by being slowed down.

"*Conduction, or conductivity,*" between two bodies, or particles, of the same body refers to the transfer of heat. "*Convection,*" or the "carrying of heat," means the transfer and diffusion of heat by means of the movement of the particles composing a liquid mass, which, in this case, are the particles composing the mass of oil in the quenching bath. If the oil bath is stagnant, this diffusion of the heat will be very slow, as it will be dependent upon conductivity, rather than convectivity. The particles of the oil bath must be in continual circulation if uniformity of transfer of heat from the solid body to the oil is to be maintained. This illustrates the importance of viscosity, particularly the effect upon viscosity, due to changes of temperature of the oil.

As the quenching bath is kept in continued use, its temperature is increased, and, as a result, affects in actual hardening of the steel. While this change is particularly evident when a water bath is in use, it is not so evident with an oil bath.

COMPARATIVE HEATING AND COOLING PERCENTAGES OF VARIOUS QUENCHING OILS, USING FISH OIL AS A BASIS

	Heating Time	Cooling Rate Per Hour
New fish oil	100.0	100.0
Linseed oil	89.5	119.0
Cottonseed oil	63.2	121.5
Lard oil	59.0	126.5
Whale oil	63.0	131.5
Petroleum	105.0	130.0

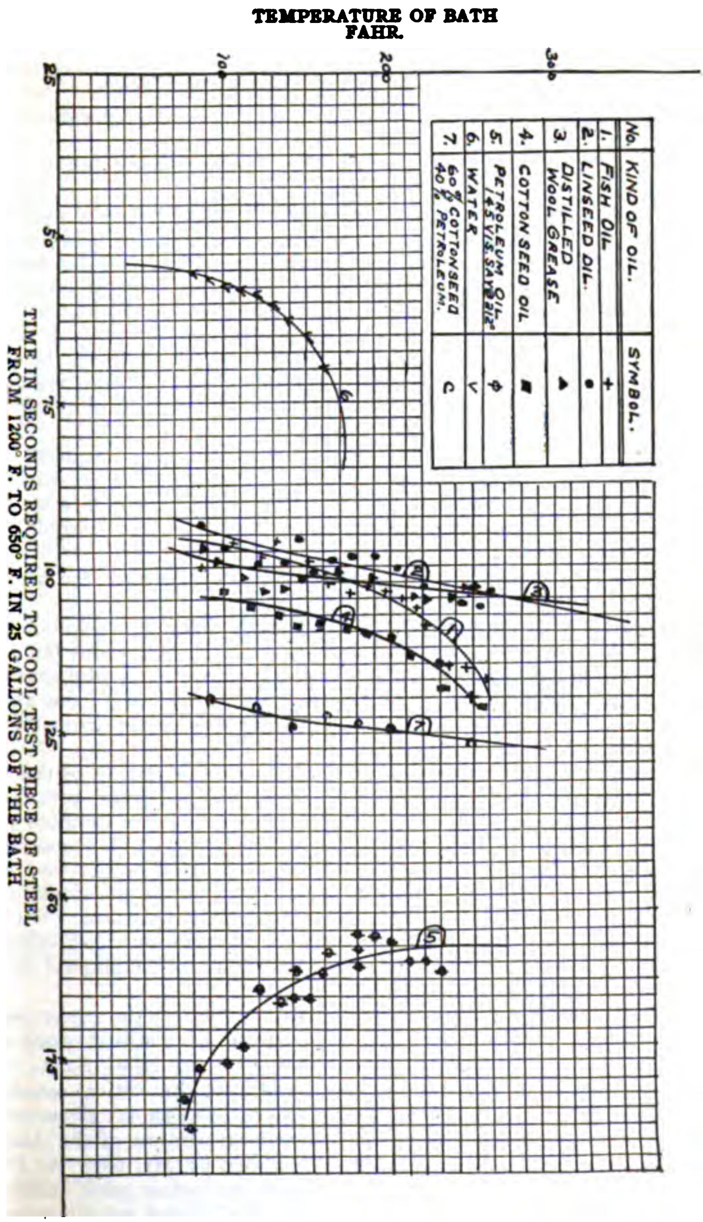


Fig. 5. Sec. 10w.—Relative quenching speeds of various mediums.

As a measure of the heat-absorbing qualities of several quenching oils, the length of time that a quart sample of each oil required in order to be heated from 50° Fahr. to 300° Fahr. was measured, using the same sized samples and a constant rate of heat for each test oil. The rate at which the sample cooled in the air per hour was also measured. (See table on page 716.)

The curves shown in Fig. 5, Sec. 10w, illustrate the relative approximate quenching speeds of various oils.

QUENCHING THROUGH OIL INTO WATER.—In some cases where very high tensile strengths are desired with large forgings, when the straight water quenching is not suitable, and still as near the maximum effect of water quenching is desired, a bath of oil floating on an equal or greater volume of water is used. The forgings to be cooled are lowered into the oil layer for a few seconds, and are then lowered on into the water. It is believed that the oil film, which was formed on the surface of the metal, offsets and controls the sudden effect of the water. By timing the period that the metal is held in the oil section of the bath the rate of cooling can be regulated to a nicety.

With thin pieces and saws, only a thin film of oil is required on the water surface. Either an animal oil or a vegetable oil, or, in some cases, special proprietary compounds of fatty and petroleum oils, are used.

This method is open to the objection that it is not possible to circulate the water or oil.

In some tool works the pieces are first quenched in a separate water tank and afterwards into an oil tank.

QUENCHING IN DISTILLED WOOL GREASE.—Wool grease itself varies from a pale-brown colored, smooth, homogeneous grease, with a very adhesive feel, to a dark-brown, grainy, semi-solid mass.

The unsaponifiable matter in a wool grease may vary from about 30 per cent. to 55 per cent. The specific gravity averages from 0.8720 to about 0.8900.

The distilled greases are pale yellow. In the distillation of the grease investigators have found that the so-called second distilled grease contains more free acid and unsaponifiable matter than the so-called first distilled grease, which is attributed by them to be the result of a partial decomposition of the neutral oils, leading to the formation of acid bodies and hydrocarbons. The oil obtained after a severe distillation possesses a very small percentage of residue and solid matter in suspension. The oil is extremely fluid and has good penetrative powers, high heat-absorbing properties and conductivity, and does not tend to decompose or fractionally distil under continued use.

Tests reported by investigators indicate that with a specimen of 50–60-point carbon steel, the quenching speed of distilled wool grease through the critical temperature range of 1500° to 1200° Fahr., was 67 seconds, as against 28 seconds for water, and from the critical range, 1200° Fahr. to 750° Fahr., was 65 seconds for the oil, as against 15 seconds for water. (See paper presented at fifth annual convention of the American Drop Forge Association, Buffalo, N. Y., written by Mr. Geo. W. Pressel.

Mr. Pressel also reports the following interesting tests, made upon various oils and distilled wool grease, for oxidation and volatilization:

OXIDATION TESTS—LIVACHE'S METHOD

(See Gill on Oil Analysis)

Reported by Mr. Geo. W. Pressel

	Per cent. gain (or loss) after 72 hours
Whale oil	7.5 gain
Linseed oil	6.7 gain
Fish	2.1 gain
Cottonseed	4.8 gain
Distilled wool grease	0.032 loss

The samples of oil were placed on cement copper on a glass plate and allowed to remain there for 72 hours, and the increase in weight, due to oxidation, after the 72-hour period, was converted into per cent. oxidation. He further states: "The results show the rapidity of oxidation on the various oils. Oils showing a high rate of oxidation are poor quenching media, as they lose many of their most important physical qualities after a short time and must be replaced frequently. The last oil (distilled wool grease) shows a very slight loss, and this is unquestionably due to evaporation. The loss sustained by the distilled wool grease is so small that it may be regarded as negligible."

Mr. Pressel made the following tests for volatilization, the test being made by heating a quantity of each oil to 212° Fahr. and 300° Fahr. for five hours, and the percentage loss in weight due to volatilization noted:

* VOLATILIZATION TESTS ON VARIOUS OILS

Made by Mr. Geo. W. Pressel

	Per Cent. Loss in Five Hours	
	At 212° Fahr.	At 300° Fahr.
Whale oil	.26	.53
Linseed oil	.72	1.27
Fish	.11	1.42
Cottonseed oil	.12	.98
Distilled wool grease	.03	.64

Mr. C. E. Waters reports in Tech. Paper No. 13, U. S. Bur. Stds., on the evaporation of mineral lubricating oils, that: "The results obtained with three mineral oils lead to the conclusion that the factor of prime importance is, for a given temperature, the area of oil surface exposed to the atmosphere. Even when quite different weights of oil are heated in vessels of the same size, the actual losses are nearly equal."

* See index.

QUENCHING DATA

It must be remembered that the degree of hardness of steel depends upon three things: (*a*) The carbon percentage which it contains; (*b*) The degree of temperature from which it was cooled and the rapidity with which it was cooled; (*c*) The resulting steel hardness varies directly with the speed of the cooling, or rapidity of heat abstraction.

If the steel is quenched in heavy oil, which has a low-heat conductivity, the steel will become hard and springy. If it is quenched in a thin oil, it becomes still harder, and this result is increased as the quenching medium used is changed to other liquids, which take away the heat faster and faster.

In all cases the quenching tank should be located as near to the furnace as possible.

It is very important that the bath have sufficient capacity and cooling facilities to prevent the temperature from rising too rapidly, as the metal is immersed, as in that case the bath would act as a sort of tempering bath.

When steel of any carbon content is quenched from above the critical range and then reheated to a point just below the range and quenched again, it is described as having been subject to "double quenching," sometimes called "double annealing."

QUENCHING SYSTEMS

METHODS OF COOLING THE -QUENCHING BATH.—The typical cooling methods are:

(*a*) Placing a small tank inside of a larger tank and filling the space in between the two tanks, with water. This is a poor method, because the inside tank must first become heated, before conducting any quantity of the heat to the water, and it gives slow and inefficient service.

(*b*) A coil is sometimes placed inside of the tank and circulating water is run through this coil to carry off the absorbed heat. The simplest form of coil should be used for this construction. This method is likely to give uneven oil temperatures, due to the uneven circulation about the coils. Also a leaky coil will cause foaming of the oil and overflowing of the tank.

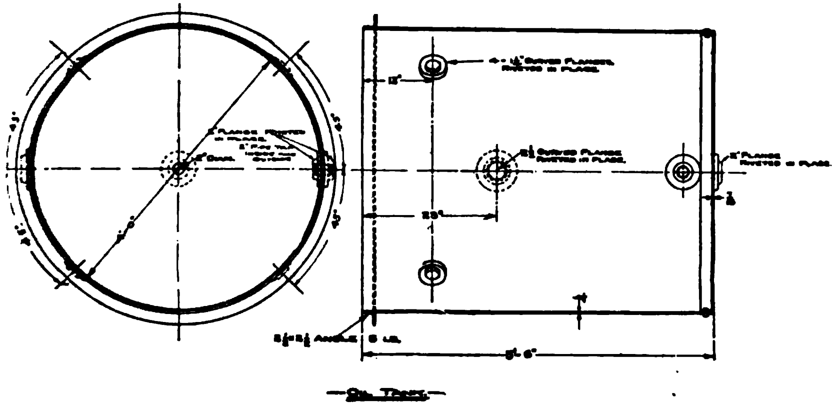


Fig. 6. Sec. 10w.—Oil quenching tank. See Fig. 7, Sec. 10w, for coils and cooling tank to complete unit.

(*c*) The best method seems to be the circulation of the oil through a coil outside of the tank, and to have this coil immersed in a cooling bath, or stream of water.

(*d*) In some plants, the oil is circulated outside of the tank, through a refrigerating coil.

(*e*) Compressed air may be circulated through the oil. This method is not satisfactory, because if the air comes into contact with the hot steel, it will soften it in spots. Also, if this method is used in too great quantities with low-grade and heavy oils, it may result in the formation of scum and also precipitate certain compounds in the oil. Air circulation should not be used with animal or vegetable oils, due to oxidation.

CIRCULATING OIL SYSTEM.—The inlet for these baths is at the bottom and the outlet at the top. A circulating pump forces the oil into the tank, and the overflow is carried back through a cooling coil, located in a large cooling tank. A typical installation is shown in Fig. 6, Sec. 10w, and Fig. 7, Sec. 10w. From the cooling coil the oil is again

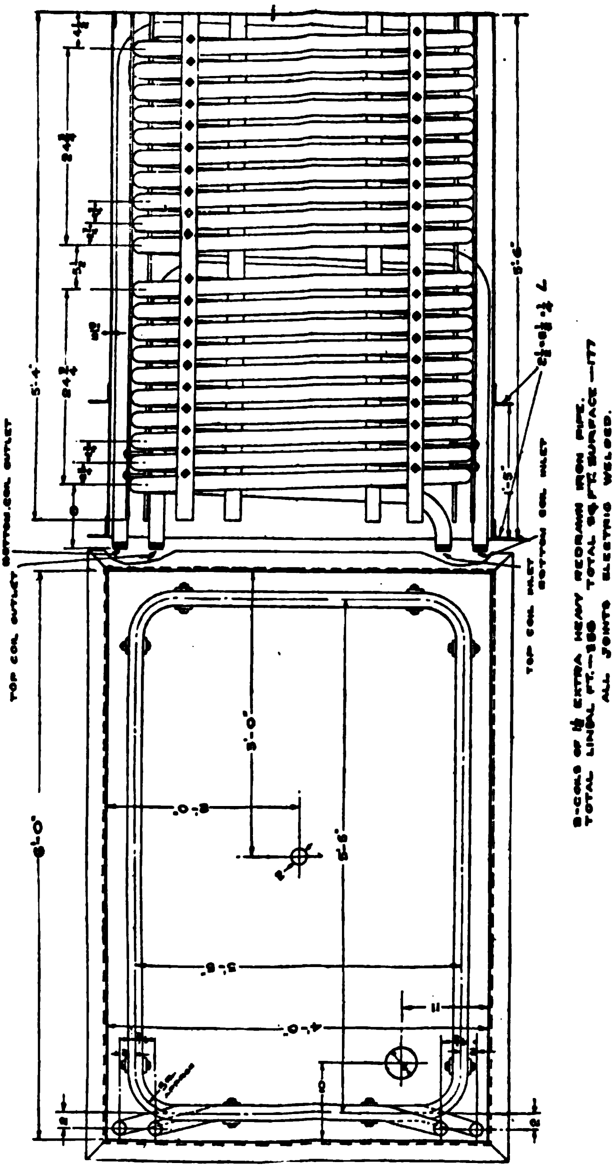


Fig. 7. Sec. 10w.—Arrangement of cooling coils and cooling tank.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

returned to the tank. Care must be taken to insure that there are no air leaks in the coil or piping and no water leaks in the coil.

The cooling tank is an important unit in the circulating system. The function of this tank is to receive the hot oil from the quenching tank and to cool it to the right temperature before being delivered to the circulating pump again. It must be designed with sufficient size to permit of the insertion of a coil which will give the right velocity to the oil and sufficient cooling capacity.

NOTE. See section on Oil Coolers.

CALCULATIONS

SPECIFIC HEATS.—The following table gives the specific heats of some solids and liquids. The actual specific heats of all substances, in the solid or liquid state, increase slowly as the body expands or the temperature rises. More complete tables for various temperature ranges may be found in the Smithsonian Physical Tables:

SPECIFIC HEATS OF VARIOUS SOLIDS AND LIQUIDS

Water	1.000
Steel (soft), according to Kent	0.1165, for average values average temperature
Steel (hard), according to Kent	0.1175, for average values average temperature
Steel (1550° Fahr.)	0.166
Petroleum (Pennsylvania)	0.5000, according to Redwood
Petroleum (Texas)	0.4009, according to Redwood
Petroleum (California)	0.3980, according to Redwood

The specific heat of oil varies with its composition. It will be greater the richer the oil is in hydrogen and lower in proportion as its carbon content is higher.

QUENCHING TANK—HEAT CALCULATIONS.—When large amounts of metal are to be quenched, it is necessary to cool the oil. To arrive at the proper amount of cooling facilities to be required, the following method of calculation may be used as a basis, taking the quenching temperature as 1550° F.

The specific heat of steel at 1550° Fahr. is taken as 0.166. Assuming that the steel is to be cooled to 200° Fahr. Then:

$(1550 - 200) \times 0.166 = 224.1$ B. T. U. taken from the steel per pound.

The number of pounds of steel to be quenched per hour multiplied by 224.1 is the number of B. T. U. which must be extracted from the oil per hour by the cooling system, since that is the amount of heat that must be absorbed by the oil from the steel.

As an illustration, assume that no facilities were made for cooling, and that an oil weighing 7.26 pounds per gallon and having a specific heat of .490 was used. Then:

$7.26 \times 0.490 = 3.487$, which is the number of B. T. U. that the oil will absorb for each degree of temperature rise.

Then for one pound of the steel quenched, as above described, in one gallon of the oil:

$\frac{224.1}{3.487} = 64.°$ Fahr. rise in temperature per hour of the oil without a cooling system.

The length of the pipe coil required in the cooling tank to keep the temperature of the oil within the desired temperature limits can then be estimated, bearing in mind that it is dependent also upon the temperature of the cooling water, the speed of circulation through the coil, the quantity of oil circulated and the circulation of the cooling water. (See section on Oil Coolers.)

PRACTICAL DATA

QUENCHING PRACTICE.—One plant making auto springs used a quenching oil of 390° flash with success.

Mexican fuel oil was used in one plant for quenching gears. It was noticed in this plant that steel quenched in this oil collected a scale on its surface, which was believed to be due to the tar and carbon in the oil. This scale did not affect the steel otherwise.

A prominent metallurgist estimated that one (1) gallon of oil was used for each 10 tons of steel treated.

When hardening high-speed steel for cutting tools, for use on shapers, slotters, planers, and lathes, the nose of the tool should be heated to a bright red slowly, then bring the tool rapidly to a white heat—about 2250° Fahr. on the point—then quench quickly in oil, and leave in bath until cold. For dead hardness, on the cutting edges, some shops quench in thin lard oil, and, for extreme hardness, even kerosene oil is sometimes used.

Oven furnaces are used to heat high-speed steel tools, such as dies, taps, milling cutters, etc. To get the best results, two furnaces should be used, one for preheating and the other to complete the heat. The tools should be put into the preheating furnace until they have reached a temperature of about 1400° to 1500° Fahr. Then place them in the high-speed steel oven, where they are heated to 2100° to 2250° Fahr., according to the make of steel. When the heating is completed, they should be plunged into a bath of thin oil and moved around, to prevent a vacuum forming, until the tool is cold.

Oil quenching does not produce as great a shock to the steel as does quenching in water. When a very hard piece is desired, water covered with a few inches of oil may be used, as previously described.

When putting a piece in the tank, it should never be thrown in and allowed to lie on the bottom of the tank, because the side exposed to the oil will cool faster than the other side, and warping will occur. If the piece is thin in one part and thick in another, the thick parts should be allowed to come into contact with quenching medium first. In order that the liquid may cover the maximum amount of surface in the shortest time, the piece should be put into the bath in the direction of its axis of symmetry. For instance, when hardening a gear, put it into the bath in a direction perpendicular to its plane, and when hardening a shaft put it in in a direction at right angles to its axis.

In order that a film of vapor will not collect over the surfaces of the piece, which would retard the evenness of the cooling, the piece should be moved about. Thin pieces should always be oil quenched to prevent warping and cracking.

Steel that has been hardened in oil is less liable to spring than is steel that has been hardened in water; also there is less tendency to crack. For hardening thin pieces, an oil bath is best. Sperm oil is satisfactory for hardening springs. Raw linseed oil can be used to advantage for hardening cutting tools. Oil hardening gives toughness to the steel.

Metal-cutting saws may be hardened between iron plates, whose surfaces are kept oiled. The saws should be heated on a flat plate, in such a manner that the fire does not come into contact with them. The

saw is then put onto the lower oiled plate and the other plate placed on top, and held there until the saw is cool. This will prevent warping.

When hardening high carbon steel, such as dies, taps, drills, shapers, slotters, etc., oven furnaces are generally used, although two methods are found in use. In one method the piece may be submerged in a lead bath, which is heated. The other method is to heat the piece in an oven furnace, being sure that the temperature is correct (generally between 1400° and 1550° F.). The steel must never be overheated, nor may it be too quickly heated. If the steel is allowed to "soak," its surface will be decarbonized. If the steel is heated too quickly, excessive contraction and expansion will result. After the piece has been thoroughly heated, it should be quenched on a rising temperature. Quench in heavy or thin oil, or water—ice water, or brine may be used—the quenching medium used depending upon the kind of work. The rate of cooling increases with each bath, from heavy oil to brine. (See other sections.)

ANNEALING

ANNEALING.—Annealing is the process of removing hardness, by careful uniform heating and slow cooling. The steel in this state is softest and toughest. Metals that have become too brittle, due to rolling in the mill or by forging, may have their properties restored by annealing.

For annealing, the heat is higher than for hardening. A method of annealing is as follows: The metal is packed in granulated charcoal (carbon) in an iron box. The cover of the box is then placed tightly on, and the box is placed in the furnace. It is heated slowly to the desired temperature, which usually varies from 1375° Fahr. to 1750° Fahr. The temperature depending upon the steel, the lower the carbon content, the higher the heat. The parts are then cooled slowly in the box. Charred bone, fire clay, sand, slacked lime, charred leather, sawdust, magnesia, or mica are sometimes used in the place of charcoal as substitutes.

Ordinary annealing is a loosely used term, and generally refers to reheating the piece to some temperature, either slightly above or below the critical range, followed by a slow cooling, either in the air, or otherwise, according to the size of the piece.

When the piece is to be made soft, the terms "dead annealing," "soft annealing," or "dead soft annealing," are used.

Annealing, known as "normalizing," consists in reheating to a temperature above the critical range, holding the piece at that temperature for a certain length of time, and then allowing it to cool in the air.

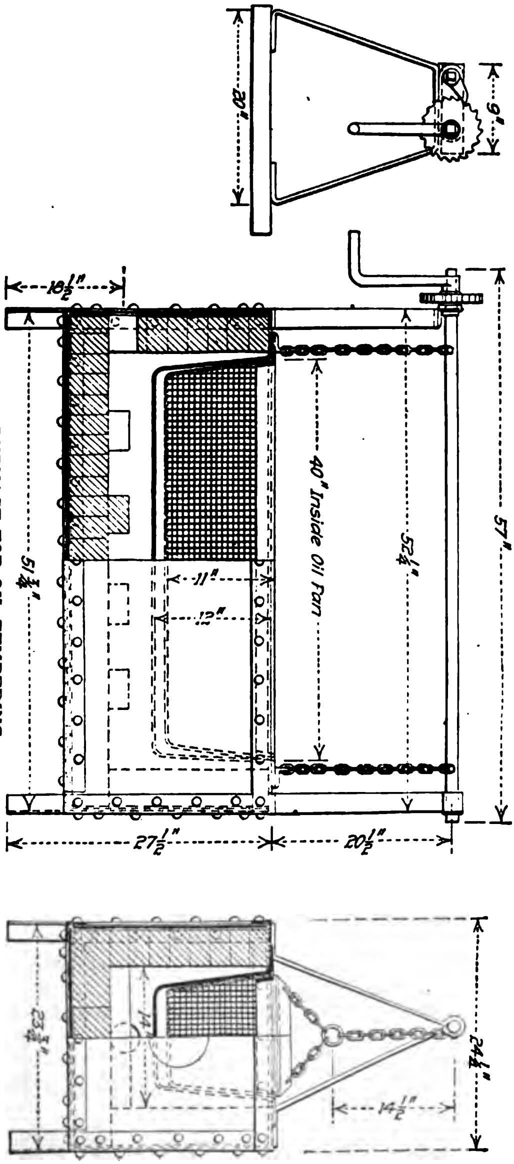
"Close annealing," "pot annealing," or "box annealing" refers to protecting the material from oxidation, which would come from heating directly in the air, by enclosing the piece in a metal box or pot.

TEMPERING

* **TEMPERING.**—When steel that has been hardened is too brittle to be used, it may be tempered. The tempering operation consists in reducing the degree of hardness by reheating the steel to a definite temperature that is between the normal air temperature and the temperature at which the steel was quenched. Some of the softening carbon will then have formed. This temperature may run from 400° Fahr. to 600° Fahr. Tempering reduces the brittleness and hardness and increases the toughness and ductility. There are two general types of tempering operations. One, which is now considered obsolete, is color tempering, either in an oven furnace or in hot sand. The other method is by submerging the steel in a bath of lead, salt, oil, or other tempering bath.

FIG. 8. SEC. 10*w*. —Oil tempering furnace.

* Also called "letting down," "drawing," "drawing back," "draw tempering" and "toughening." Tempering is always preceded by some hardening operation, except in special cases where hardening and tempering are combined in one operation.



FURNACE FOR OIL TEMPERING

FIG. 9. SEC. 10w.—Furnace for tempering steel. (Courtesy, Machinery.)

When many pieces are to be tempered, oil is by far the best. The hardened piece is placed in the bath when it is cold and heated to the right temperature. Heavy black oil, or cylinder stocks which can be heated up to 600° Fahr., are used.

For heavy tempering, such as car springs, wagon springs, etc., an oil with a high flashing point, such as petroleum cylinder stock, is recommended. A suitable oil for this purpose will have the following general tests:

Gravity: 25° B.	Viscosity: About 180 at 212° Fahr.
Flash: 600° Fahr.	Dark.
Cold test: 28° Fahr.	

For light work and small parts a lighter oil should be used. A typical oil would have the following general tests:

(A)	*(B)*
Flash: 375°–400° Fahr.	Flash: 400°–420° Fahr.
Viscosity: 130 at 100° Fahr.	Viscosity: 280–295 at 100° Fahr.
Cold test: 25°–30° Fahr.	Cold test: 25°–30° Fahr.

NOTE. Oil (*A*) is for very light work, and oil (*B*) is for use with heavier work.

Oil baths for tempering, as well as other types of baths, are provided with baskets made of wire, in which the pieces to be tempered are placed when they are to be lowered into the tempering bath.

Oil-tempered steel is more elastic. For instance, the heavy oil listed above, flashes at 600° Fahr., and if the piece is covered with the oil and the oil is burned off, the resulting temperature will be practically 600° Fahr. The bath of oil is sometimes heated to an exact temperature, to draw the temper of a series of pieces the same.

For a description of the use of oil coolers to cool the oil used in tempering baths, see index.

OIL TEMPERING FURNACES.—Fig. 8, Sec. 10w, shows a view of an oil tempering furnace, manufactured by the Standard Fuel Appliance Co., of Detroit. The furnace as shown is gas fired. A strongly made wire basket and an accurate thermometer are a part of the equipment.

Fig. 9, Sec. 10w, shows a furnace for oil tempering steel parts. Mr. G. E. Baldwin, in an article in the *American Machinist*, vol. 49, No. 7, p. 316, describes the furnace as follows: It consists of a brick furnace, inclosed in a steel jacket. In this is suspended an oil pan, lined with a wire basket, which may be raised or lowered by chains, fastened on the end of a shaft that is supported by wrought-iron baskets and operated by means of a crank.

EFFECT OF TIME IN TEMPERING STEEL.—There is a definite effect, due to the time consumed in reheating steels below the critical range. Steel, that has been subjected to a long, high drawing temperature, has increased toughness. It also has higher shock-resisting power and better machinability.

Mr. A. E. Pellis, in a paper presented before the American Institute of Mining Engineers in 1918, reported some interesting data on the effect of time in the tempering of steel, in connection with the manufacture of rifle-barrel steel. He states that: The time effect is most important, when a maximum drawing effect is desired, in which case maximum physical properties as well as ease of machining are important considerations. * * * The physical properties of two different lots of rifle barrel steel are given below. The first lot, No. 1, gave serious trouble in the drilling operation. The second (lot) gave no trouble at all. Mr. Pellis describes the conditions in drilling a rifle barrel by stating that a hole 0.30 inch in diameter and 24 inches in length, for the Springfield rifle, and 30 inches long for the Russian rifle, must be drilled through the heat-treated steel. The properties of the two lots above mentioned are given by Mr. Pellis as follows:

	No. 1	No. 2
Elastic limit, pounds per sq. inch	117,450	116,800
Tensile strength, pounds per sq. inch	132,500	131,750
Elongation, per cent	16.0	20.0
Reduction of area, per cent	42.1	51.0
Impact strength, foot pounds per sq. inch	450.0	520.0

Mr. Pellis states: The difference in machining and physical properties was due entirely to the time of reheating. The first lot was given a reheating time of 30 minutes, the second lot was given a reheating temperature for 2 hours. Both lots were oil quenched from 1500° Fahr. and reheated to 1180° Fahr. The time required in reheating or drawing for the work to come to temperature was not counted. This time was approximately 20 to 30 minutes.

The steel used had the following composition: Carbon, 0.54; sulphur, 0.050; manganese, 1.22; phosphorus, 0.065. The physical properties when untreated are as follows:

Elastic limit, pound per square inch	69,800
Tensile strength, pound per square inch	128,700
Elongation, per cent.	15.0
Contraction of area, per cent.	35.2

Mr. Pellis found that: Steel, which after treatment gave an elongation of 20 per cent. or over, gave no trouble in the shops. To show the effect of time in reheating, the following table was given, as the results of many physical tests in the shops:

	Reheating Time				
	1 hour	2 hours	3 hours	½ hour	12 hours
Elastic limit, pounds per sq. inch....	124,250	121,600	116,250	115,500	98,750
Tensile strength, pounds per sq. inch	137,000	135,600	125,900	135,400	116,500
Elongation, per cent................	17.0	17.5	19.0	17.5	22.0
Reduction of area, per cent..........	42.2	45.4	47.6	52.7	57.2

Note the decrease in the elastic limit and tensile strength, as the drawing time was increased, and the increase in ductility and impact strength.

In order to determine whether this effect was largely due to the high manganese content of the steels, an ordinary machining steel of the same carbon content was tested. The steel used by Mr. Pellis for this test analyzed as follows: Carbon, 0.53; sulphur, 0.036; manganese, 0.65; phosphorus, 0.049. Four specimens of this steel were oil quenched from 1500° Fahr. and drawn at 1180° Fahr. for periods of 1/2, 1, 2 and 4 hours, respectively. The results were as follows:

	Reheating Time			
	½ hour	1 hour	2 hours	4 hours
Elastic limit, pounds per sq. inch......	66,150	63,800	62,750	61,600
Tensile strength, pounds per sq. inch...	101,250	98,250	97,250	96,600
Elongation, per cent................	23.0	26.0	28.5	28.5
Reduction of area, per cent..........	60.8	67.5	65.0	65.8

The original diameter of the test piece was 1 1/32 inch. The time for reheating necessary for the pieces to reach furnace temperature averaging about 20 to 30 minutes, was not counted.

A straight mineral oil was used of 0.890 specific gravity at 60° Fahr., 400° Fahr. flash, 200 Saybolt at 100° Fahr.

SPRING STEEL.—*Machinery,* Railway Edition, May, 1910, gives an abstract from a paper by Mr. Lawford H. Fry, read before the Copenhagen International Association for Testing Materials, as follows: A number of experiments were undertaken at the Baldwin Locomotive Works to determine the effect of different kinds of heat treatments upon the transverse elastic limit and modulus of elasticity of steels used for locomotive springs. (See below for definition of terms used.) Points investigated were: effect of quenching in water and oil, and the effect of reheating the steel to various temperatures after complete cooling in water or oil. The steel experimented upon was basic open-hearth spring steel, of the following composition:

	Per Cent.
Carbon................	1.010
Manganese.............	0.380
Phosphorus............	0.032
Sulphur...............	0.032
Silicon...............	0.130

* * * The investigations were carried on at the following temperatures:

For annealing	1400° Fahr.
For quenching in water	1425° Fahr.
For quenching in oil	1450° Fahr.

The following conclusions were reached: The highest elastic limit obtainable with the steel used, when quenched in oil, after having been heated up to 1450° Fahr., was 187,000 pounds per square inch, and this was obtained when the temper was not drawn after quenching. The higher the temper was drawn, the lower the elastic limit fell. * * * Drawing the temper to 600° Fahr., after having hardened in water, gave an elastic limit of 219,800 pounds. When the temper was drawn to 1050° Fahr., the elastic limit dropped to 180,700 pounds, but the test piece did not break at 1.1-inch deflection. The results of the tests show, that the modulus of elasticity is practically independent of the heat treatment given.

ELASTIC LIMIT.—When a test piece of metal is pulled in a testing machine, and the stretch of the piece is measured, that point or load per square inch at which the rates of elongation increase at a higher ratio and are no longer proportional to the loads, is called "Elastic Limit."

YIELD POINT.—This is the point, or load, at which the test piece. as above described, suddenly increases its rate of stretch, when being pulled in the testing machine.

MODULUS OF ELASTICITY.—This may be defined as the load per square inch of cross-section of the test piece, divided by the extension per unit of length.

BLAZING OFF.—This is sometimes called "burning off," or "oil flaring," and is a method of tempering, sometimes used for springs, which consists in heating the piece, coated with oil, the oil coming either from the quenching bath or other sources, until a temperature is reached, just high enough to cause the oil to burn easily in the air.

SECTION 10x

HYDRAULIC EQUIPMENT

HYDRAULIC LUBRICATION

HYDRAULIC LUBRICATION.—A lubricating film composed of pure water has little resistance to tear. Therefore, water has little value as a lubricant for the valves, etc., of a hydraulic system, since metallic contact between the surfaces will occur.

If soap is added to the water, the resistance to tear is increased in the film and lubrication may be secured.

In the case of hydraulic pumping engines, the engines must deal with the full load at once on all bearing surfaces. With oil lubrication, the lubricating film is thin and the projections on the bearing surfaces interlock, thus causing sticking and groaning and high frictional resistance. This continues until the speed has increased to trap sufficient of the oil to form a lubricating film that is thick enough to remove the tendency of the surface projections to interlock. For this type of machinery, grease lubrication, with the resulting thicker films of lubrication, is preferable, as a lower starting friction will result.

CONDENSATION IN STEAM CYLINDERS.—When considerable condensation occurs in steam-engine cylinders and the condensation water cannot get away freely, efficient lubrication is difficult. This is due to the fact that the water comes into contact with the metal first, and the oil, being a liquid of lower surface tension, cannot displace the water.

This condition can only be overcome by coating each minute drop of the water in the steam with oil, so that the oil will reach the metallic surfaces first. Then there will be a surface of oil, which, though of lower surface tension, is in close alliance with the metallic surfaces, and is not displaced by the water; the oil presenting in this case a solid surface to the water.

SURFACE TENSION BETWEEN OIL AND WATER.—(Wells and Southcombe, *Jour. Soc. Chem. Industry,* Vol. xxxix, No. 5, pp. 51T-60T): " On proceeding to measure the interfacial tension, *i.e.,* the surface tension between oil and water by the drop pipette * * * in which a series of mineral oils and then a series of animal and vegetable oils and compounded oils, it was found that the interfacial tension against water of the vegetable and animal oils is much lower than in the case of mineral oil. * * * The lowering of interfacial tension in the case of fatty oils was due to their slight content of free fatty acid." The following table shows some of the results as found by Messrs. Wells and Southcombe:

Oil	Free fatty acids, calc. as oleic	Drop No.	Interfacial tension
0·905 mineral	nil	101	100
98% mineral 2% com. fatty acids	1·9	125	80
97% mineral 3% com. fatty acids	2·8	130	78
Olive	2·2	125	80
Olive	4·5	140	72
Rape	2·5	132	76
Cocoanut	4·1	148	68
Olive (neutral)	0·1	110	92
Rape (neutral)	0·15	108	93

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

SECTION 10y
INTERNAL COMBUSTION ENGINES

FOUR-CYCLE ENGINES (EXPLOSIVE TYPE)

The greater part of the internal-combustion engines of the explosive type in active use are operated on the four-cycle principle.

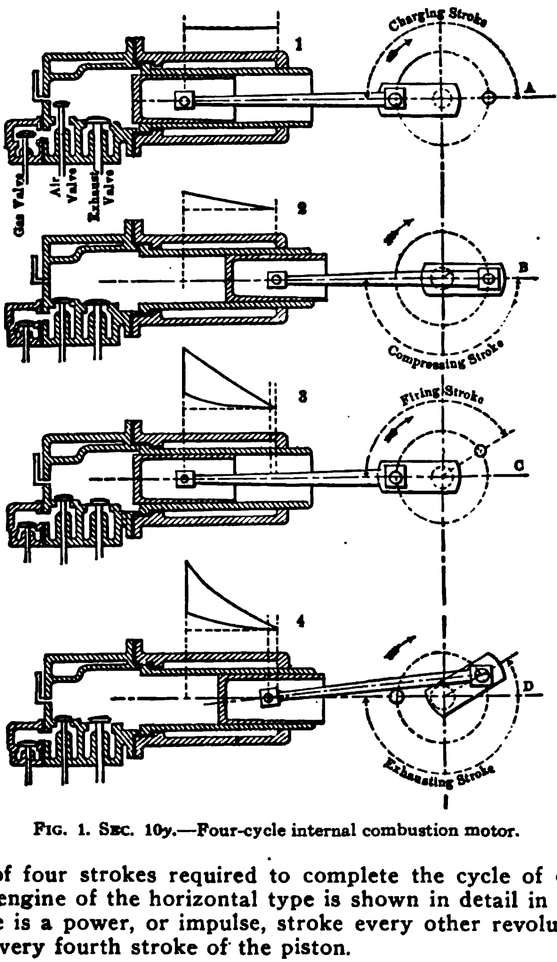


FIG. 1. SEC. 10y.—Four-cycle internal combustion motor.

Each of four strokes required to complete the cycle of events in a four-cycle engine of the horizontal type is shown in detail in Fig. 1, Sec. 10y. There is a power, or impulse, stroke every other revolution of the crank, or every fourth stroke of the piston.

Referring to Fig. 1, Sec. 10y, in the first outward stroke *A*, the mixed charge of gas and air is drawn into the cylinder. This is called the "charging stroke." On the return stroke *B*, the air and gas valves are closed and the contents of the cylinder are compressed. This is called the "compression stroke." At or near the end of the "compression stroke" the compressed gas is ignited by means of an electric spark, hot tube, hot bulb, or some other means of ignition. Expansion due to the temperature rise and resulting volumetric increase takes place in the charge, as the piston is moving outwards. *C* is called the firing stroke. On the return of the piston, the fly-wheel, which has been given enough momentum, carries the piston back. The exhaust valves have been opened and the burnt gases are displaced. This stroke *D* is called the exhaust stroke.

COMPRESSION.—In the usual internal-combustion engine, using gasoline or similar fuels, the compression is carried up to about 90 pounds per square inch.

PISTON SPEEDS.—Usually piston speeds are between 500 and 700 feet per minute, but in some cases may be outside of these limits.

INDICATOR DIAGRAM.—The corresponding parts of the indicator diagram are shown above each of the strokes in Fig. 1, Sec. 10y.

TWO-CYCLE ENGINES

The fundamental difference between two- and four-cycle-engine operations should be thoroughly understood. In the four-cycle engine all of the operations take place separately, within the cylinder and above the piston, while in the two-cycle engine, either of the two- or of the three-port type, the operations take place on both sides of the piston, or within the cylinder and within the crank-case. Two operations occur at each stroke in the two-cycle engine, while in the four-cycle engine only one operation occurs for each stroke.

In the two-cycle engine, as the piston ascends in the cylinder, the exhaust ports are closed and the explosive mixture is drawn into the crank-case, through the carburetor and check valve. This stroke is called the crank-case inlet stroke. The piston next descends and compresses the charge in the crank-case, and when it is at the bottom of its stroke the port closing the passageway between the crank-case and the cylinder is opened and the gas that was compressed in the crank-case escapes into the cylinder. Then the piston ascends, the inlets and outlets, or exhaust ports being closed, and compresses the charge in the cylinder, while at the same time a fresh charge is being drawn into the crank-case below. When the top of the upward stroke of the piston is reached, the charge is ignited and the resulting expansion of the gases delivers power to the piston and thence to the crank-shaft. When the piston reaches the end of its power stroke, the exhaust openings are opened and the burnt gases escape, while at the same time the gases in the crank-case are admitted to the cylinder, striking a deflector, which directs them to the top of the cylinder, which aids in blowing out, or scavenging, of the cylinder, and then the operations as described are repeated. This description covers the two-port engine. The piston speeds are usually lower in two-cycle engines than in four-cycle engines.

In the three-port engine there is a third port, which leads to the carburetor from the crank-case, and no check valve is required between the crank-case and the carburetor, as is the case with the two-port engine.

In the three-port engine, as the piston ascends on the inlet stroke, an increasing vacuum is created in the crank-case until the lower part of the piston uncovers the third port, above described, when the mixture from the carburetor rushes into the crank-case. The piston then descends and covers the third port and compresses the charge in the crank-case, until, at the lower end of the piston stroke, the inlet port to the cylinder is uncovered by the piston and the compressed charge escapes into the cylinder. The piston then moves upward and compresses the charge, as in the case of the two-port engine, and the operations in the cylinder are the same as for the two-port engine.

TWO-CYCLE VS. FOUR-CYCLE MOTORS.—The four-cycle motor is well adapted to high-speed work, since it has a separate suction and exhaust stroke, thus permitting the cylinder to be filled each time with a full fresh charge, and, generally, in comparison with a two-stroke cycle motor, the four-stroke cycle motor uses less fuel per horse-power. The four-cycle motor does not require a scavenging pump, air receivers, etc., and its construction is relatively simple. It is comparatively higher in weight and occupies greater space, and generally has a greater number

of valves with a more complicated valve gear. The exhaust valves are subjected to high temperatures, and may give some trouble. This type of motor is widely used in the Danish and the Dutch merchant marine.

A two-stroke cycle motor has a comparatively greater output per cylinder. all else being equal, than the four-stroke cycle motor. The weight of the charge for equal stroke volumes are greater, since the pressure is greater at the beginning of the compression stroke. However, the power is exerted only during about three-fourths of the stroke, and during the remaining part of the stroke exhaust occurs, so that the total stroke volume is not completely filled with a fresh charge at the beginning of the compression, and for the same dimensions of cylinders. the output, with a two-stroke cycle motor per cylinder, is only about 75 per cent. greater than for a four-stroke cycle motor. In large units, only the starting and fuel valves are subjected to high temperature. With a two-stroke cycle motor, a closed crank-case is used, so that the vapor, from the lubricating oil and exhaust gases, does not escape into the engine-room and give bad-air conditions, as is often met with in the open-type four-stroke cycle motor. In general, a more uniform torque and smooth running is accomplished with the two-stroke cycle engine. The two-stroke cycle motor generally has a higher operating cost, due chiefly to its high loss of fresh-air charge through the exhaust ports, and higher heat loss, due to cooling, and increased pump work, and also to smaller utilization of the fuel. The mean effective pressure is lower, since the exhaust occurs during the working stroke. The piston must be cooled, since the mean temperature during the two-stroke cycle is higher than during the four-stroke cycle. The consumption of lubricating oil is higher, and generally the exhaust ports must be water-cooled to prevent overheating. The moving parts must be large, with ample sliding and bearing surfaces, to carry the high stresses.. The merchant marine of the Scandinavian countries, Germany and Italy, have been the largest users of the two-stroke cycle motor for marine purposes.

HIGH-PRESSURE-TYPE MOTOR.—The high-pressure-type motor, having self-ignition and injection of the oil, during the high-pressure stroke, is about the same as the intermediate-pressure motors, with water injection, as far as advantages are concerned. However, high-pressure motors, which are usually operated with an oil chamber, are economical, and have a high mean effective pressure, with small cylinders, low weight, and can be started without much preliminary preparation. The oil chambers and atomizer holes must be properly proportioned as to size, or the fuel-oil consumption will increase. Pressure air is necessary for starting the motors.

HOT-BULB-TYPE MOTOR.—The hot-bulb type of motor operates at a medium pressure, and may operate with or without water injection. The tendency to-day is to avoid water injection. However, with the hot-bulb motor, operated with water injection, the fuel consumption will be comparatively low, and the temperature of inlet air low, and overheating of the cylinder and piston will seldom occur. Also, the cylinder will be cleaner for a longer time, and the piston rings will not tend to gum or stick. However, there is a tendency for corrosion and rust, especially if in marine practice, in order to conserve cargo space, the water taken is not used, and sea water is used for injection. The amount of water

injected should be regulated according to the load, and this necessitates more or less constant supervision. If the intermediate-pressure motor is not operated with water injection, while there is some difficulty in properly timing the fuel-oil supply, as its injection against the highly compressed air is difficult in the short time given before ignition occurs, the cost of maintenance is lower, the mechanism is simpler, and little attention is required.

THE STILL ENGINE.—(Capt. F. E. D. Acland, in paper published in *Journal of Royal Society of Art*, June, 6, 1919, abstracted through *Journal of A. S. M. E.*, Vol. 41, No. 7, July, 1919): The paper by Capt. Acland, describing the possibilities of combining an internal-combustion motor

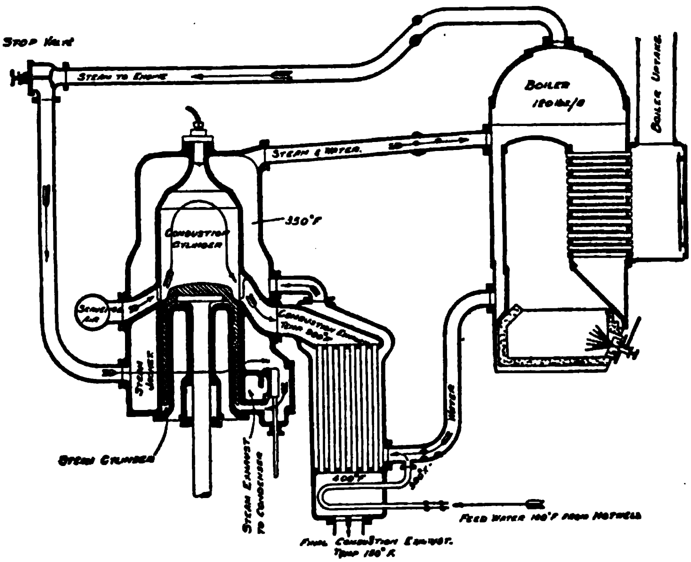


FIG. 2. SEC. 10y.—Diagram showing arrangement of Still engine.

with a steam motor, with a view to improve the thermal conditions of the working cylinder, and to secure the maximum efficiency from the fuel burned, is interesting, inasmuch as a thermal efficiency of 50 per cent. has been claimed for this type of equipment. Capt. Acland gives some interesting data, regarding the " Still engine, as follows:

The Still engine, Fig. 2, Sec. 10y, showing a diagram and arrangement of the engine, is an engine capable of using in its main working cylinder any form of liquid or gaseous fuel; it makes use of the recoverable heat which passes through the surfaces of the combustion cylinder, as well as into the exhaust gases, for the evaporation of steam, which steam is expanded in the combustion cylinder itself, on one side of the main piston. * * * The combustion stroke acting on the other side. * * * It increases the power of the engine, and reduces the consumption of the fuel per horse-power developed. * * * Its primary object is not to

use the waste heat for raising steam, but first to use it in improving the thermal conditions of the working cylinder, and to so insure the maximum efficiency from the fuel burned within it, diminishing the heat lost in that operation. Since the maximum efficiency is obtained by the combustion of the fuel in the cylinder, and the mimimum by the evaporation of the steam in the water generator, it is evident that the larger the quantity of steam which can be generated per horse-power developed, by the combustion cycle, the lower must be the heat efficiency of the whole machine.. In the Still engine, the jacket and cooling water form part of the circulating system of the steam generator, which may be an integral part of the engine or external to it. The cooling water enters and leaves the jacket at a constant temperature, regulated by the temperature of the steam, the cooling being effected by converting the water into steam without raising its temperature, and excluding the radiation losses, which are kept low by lagging, all of the heat which passes through the walls is thus usefully recovered in the water as steam. * * * The temperature of the cylinder wall is uniform over the whole of its exterior surface, and the heat lost to the cooling water at each stage of the cycle—compression, combustion, and expansion—is diminished. The exhaust gases, after raising their quantum of steam, are employed in preheating all the water required for the steam generated in the jacket water of the generator. * * * Trials at full efficiency over long periods and steady loads, show terminal stack temperatures as low as 150° Fahr. The quantity of steam capable of being generated from " waste heat " depends upon the efficiency of the combustion cycle and the load. Some years of experimental work prove that the rate of steam recovered may attain a maximum of about 7 pounds per B. H. P. hour developed by the combustion cycle of a four-stroke cycle, constant-volume engine at full load. The first experimental engine constructed was a two-stroke engine capable of developing 590 B. H. P., from 3 cylinders, at 400 revolutions, bore 8 inches. It was a high-speed engine, designed with special regard to obtaining data about the recovery of steam from waste heat (jacket and exhaust). It was first operated on town gas with 540 B. T. U. per cubic foot, and subsequently converted for oil fuel. Its efficiency was not high, owing to its being a two-stroke engine, with short stroke, but its consumption per B. H. P. was 15 cubic feet per hour (31.3 per cent. efficiency). * * * The progress made in the design and construction of gas engines, and the results accomplished give promise of future development, for with a combustion indicated efficiency of 36 per cent., radiation 4 per cent., boiler loss 10 per cent., there remains 50 per cent. for recovery; allowing 10 per cent. efficiency for the steam cycle, a gain of 5 per cent. is assured, and the total indicated efficiency of the engine will not be less than 41 per cent. If 20 per cent. efficiency is obtained from the steam cycle, as appears possible, the total indicated efficiency will be 46 per cent.

* * * Four-stroke engines for petrol and similar fuels have been built and tested ashore and afloat. A special 13 1/2 x 22-inch two-stroke cycle, heavy-oil engine, with opposed pistons, has been tested by representatives of various Governments. The combustion takes place between the piston, the steam acting on the return stroke, at the back of both pistons. The best consumption of fuel, Admiralty shale oil, was as low as 0.302 pounds per B. H. P., scavage pump not included, over a test of

one-hour duration. This engine developed 330 B. H. P. for six hours at 360 R. P. M., a single cylinder, under waste-heat conditions. It will develop 400 B. H. P. continuously, with added steam, generated by fuel under the boiler, and has developed 540 B. H. P. at 380 R. P. M. over a short period. Combustion M. E. P., 128.2 pounds; steam M. E. P., 57.9 pounds; total M. E. P., 186.1 pounds. The thermal brake efficiency, from below quarter load to full power, is maintained at approximately 40 per cent. over the whole range. The application of the Still system to commercial marine work is developed. The two-stroke, single piston type, in powers of 100 horse-power per cylinder, and 400 horse-power per cylinder, having been adopted. Engines of this type, at 120 R. P. M., with a 22 x 36-inch cylinder, giving 4200 shaft horse-power on two shafts, with all auxiliaries and water, would approximate 600 tons. A geared turbine plant in a similar ship would weigh 20 per cent. more, and would consume approximately 2000 tons more fuel for a double journey lasting 1000 miles.

The above description of the Still system should be of interest to all engineers, in connection with the improvement of the thermal efficiency of internal-combustion oil motors, particularly for marine purposes.

FUELS

VARIOUS FUELS.—Natural gas, blast-furnace gas, producer gas, coke-oven gas, etc., are comparatively slow burning. They do not produce high initial temperatures, but, due to the fact that they are generally used in low-speed engines, on account of the time required for complete combustion of the fuel, a thicker oil film is required for protection against the long exposure of the film to the burning gases.

Kerosene is slow burning and permits of higher compression than gasoline. It requires somewhat higher temperatures of the cooling water, and thus the lubricating conditions are more severe.

COKE-OVEN AND BLAST-FURNACE GASES.—The waste gases from coke ovens are cleaned and used for power purposes. These gases are rich in hydrocarbons. Blast-furnace gases also are cooled and cleansed and used in the engines of the adjoining plants.

PRODUCER GAS.—The most important of the so-called fuel gases is Producer Gas. The apparatus used for generating this gas is called a "producer," and it is usually supplied with a small-sized anthracite coal, as fuel.

There are in common use two types of producers. In one type, air or steam (or both together) is forced, under pressure from a blower, up through a bed of solid fuel in the producer. In the other type, the suction of the charging stroke of the engine itself draws the air and steam through the bed of fuel. This last type is called a "suction producer."

ILLUMINATING AND NATURAL GAS.—Illuminating gas from the city mains and in certain restricted areas, where available, natural gas, is used as fuel for internal-combustion engines.

CALORIFIC VALUES.—Some approximate idea of the calorific (heat) values of the various gas-engine fuel gases may be obtained from the following table:

Gas	B. T. U. per Cubic Foot
Natural	725–1760
Water	295
Coal	595– 695
Producer	135
Oil gas	846
Coke-oven gas	600
Carburetted water gas	570
Blast-furnace gas	92

CHARACTERISTICS OF FUEL GASES.—The characteristics of the various gas-engine fuel gases, which may have an influence upon the lubrication of the cylinder of the engine, using any one of them, are thus outlined:

Natural Gas.—Rich, pure, and slow burning.

Coal Gas.—Made by the destructive distillation of coal, in closed retorts. Not commonly used because of the high cost.

Producer Gas.—Usually contains some water, slow burning and lean.

Coke-oven Gas.—Good gas, but high in sulphur and hydrogen. Should be carefully cleaned and drawn off early in the oven run.

Blast-furnace Gas.—Good gas for high-compression engines. Very lean and sluggish and usually contains dust.

LUBRICATION

LUBRICATING CONDITIONS.—The lubricating conditions are more severe in a two-cycle engine than in a four-cycle engine, because the lubricating film on the walls of the cylinder is exposed to the explosion heats for each revolution of the crank, instead of every other revolution, as with the four-cycle engine. The two-cycle engine is not in general use to-day for various mechanical reasons.

TYPES OF ENGINES.—The two main types of internal-combustion engines of the explosive class are the Vertical, having vertical cylinders, and the Horizontal, having a horizontal cylinder, or cylinders, as in a tandem gas engine.

HORIZONTAL ENGINES.—Engines used for industrial purposes are usually of the horizontal, four-cycle type, with a single cylinder, or with tandem cylinders. The lubrication of the cylinders of the horizontal internal-combustion engine may be by direct feed, or by splash feed. In some engines, telescopic oilers are arranged to feed through the wrist-pin to the cylinder walls. Particular attention must be paid to the lubrication of horizontal gas engines, because the weight of the piston is carried upon the lower cylinder walls.

VERTICAL ENGINES.—There are several methods used for the lubrication of vertical combustion engines, namely: The Splash System, the Forced-feed System and a combination of the Forced- and Splash-feed Systems. Vertical gas engines have one, two, or more cylinders. Each cylinder has its own crank on the main crank-shaft of the engine. The operations of the above-named lubricating systems are as follows:

SPLASH FEED.—In the Splash System, the crank-case is of the enclosed type and acts as an oil reservoir. Each cylinder is lubricated by the splash of its crank, as it revolves and is immersed for a fraction of an inch below the surface of the oil. On its upward stroke, the oil which adheres to the end of the rod, or to the small dipper on the end of the rod, is thrown violently against the exposed parts of the cylinder walls. The piston is then depended upon to carry the oil up and spread it over the upper walls. Each upstroke of the piston brings fresh oil from the crank-case to the cylinder walls. The wrist-pin, crank-pin, and main bearings are lubricated by the splashed oil, which is caught in small pockets and led to the bearings, or, as in the case of many engines, a fin on the sides of the crank-case collects the oil draining back to the reservoir and leads it to the main bearings.

The following points are important with reference to the efficiency of this type of feed:

(*a*) The oil in the reservoir soon becomes dirty and unfit for lubrication, although it is repeatedly thrown onto the surfaces to be lubricated, when it is in this condition, and is expected to do good work.

(*b*) The distribution of the lubricant is not positive, but depends upon several varying conditions.

(*c*) The level of the oil in the crank-case must be maintained within fairly uniform limits. Too high a level causes an excess of oil to be thrown violently against the lower part of the piston, with the result that some of the oil is carried past and above the piston rings, causing excessive smoking and cylinder deposits. (See Carbon Deposits in index.)

(*d*) The viscosity of the oil used has an immediate effect upon the

amount of oil splashed, and hence upon the oil available for lubrication. The heavier the oil, the smaller the amount splashed.

FORCED FEED.—Many vertical and some horizontal internal-combustion engines are lubricated by the forced-, or positive-feed system. In the forced-feed system, the oil from the reservoir, or sump, which is located at the lowest part of the crank-case, is pumped through a fine-mesh strainer and through suitable distributing feed channels, to the various points requiring lubrication.

The oil may be carried through hollow crank, cam, and other shafts to the various bearings, or through separate direct oil feeds which lead from a central manifold, equipped with individual sight feeds and control valves which regulate the amount of oil fed.

LUBRICATION OF INDUSTRIAL ENGINES.—The following recommendations may be used as a guide in the selection of the proper lubricant, for gas engines using the following named fuel gases:

Natural gas.......	Free flowing mineral oil of about:	170 to 180 Vis. at 100° Fahr. (P. B.). 220 to 250 Vis. at 100° Fahr. (A. B.).
Blast-furnace gas: Producer gas: Coke-oven gas:	Oil having Vis. 300 to 310 at 100° Fahr. (P. B.). Oil having Vis. 500 to 550 at 100° Fahr. (A. B.). Owing to sulphur and other impurities, occurring in blast furnace and the other gases, especial care must be given to the lubrication of these engines. Forced-feed lubricators are usually used for the cylinders. The stuffing-boxes are water cooled.	
Other fuels: Gasoline Kerosene Illuminating gas	Red or pale oil of: 225 to 250 Vis. at 100° Fahr. (P. B.). 350 to 375 Vis. at 100° Fahr. (A. B.).	Industrial Stationary Engines.

DISCUSSION OF THE LUBRICATING CONDITIONS IN THE CYLINDERS OF FOUR-CYCLE INTERNAL-COMBUSTION ENGINES.—In the usual internal-combustion engine cylinder, operating upon the four-cycle principle, the charging, compression, and firing strokes do not present any particularly difficult problem from the standpoint of successful lubrication. During the exhaust stroke, however, when the piston is returning and expelling the hot exhaust gases from the cylinder, it is evident that the lubricating film remaining upon the cylinder walls, after having been subjected to the high temperatures of the preceding firing stroke, must furnish the only form of lubrication, with the exception of that oil which is being brought up by the piston itself, on this return stroke. A study of the conditions affecting the lubricating film during the firing stroke and the probable conditions of this film, with reference to its ability to furnish lubrication for the exhaust stroke, is, therefore, of the greatest importance.

In the past it was believed that lubricating oil for use in the cylinders of internal-combustion engines should possess a high flashing point, to prevent its destruction during the firing stroke. This theory has been given up for the following reason: In order to obtain a flashing point of over 500° Fahr., with a petroleum oil, it is necessary to use a cylinder

stock oil, with all of the resulting disadvantages of slow distribution of the lubricant, due to its high viscosity at normal and even fairly high temperatures. The average working temperatures in the cylinders of internal-combustion engines are far above 500° or even 600° Fahr., so that even a high-test oil will be burnt with practically as much rapidity as an oil having only 400° Fahr. flash test and a much lower viscosity. It has been demonstrated by many practical tests, that the most important characteristic of an oil, in the lubrication of internal-combustion engine cylinders, is its viscosity. The viscosity should be as low as practicable, to permit of a quick and efficient "spread" of the oil over the cylinder walls. The flashing point of the oil is of minor importance.

Due to the fact that the same oil is used for both the cylinders and the bearings of internal-combustion engines of the light high-speed type, now in most general use in automobiles, motor-boats, etc., it is desirable, and the best lubricating efficiency can only be secured, by using an oil having a viscosity, at the average running temperatures of the bearings, that is just sufficient to meet the physical operating conditions of these bearings, so that the distribution of this same oil over the surfaces of the cylinder walls will be accomplished with speed and effectiveness and not retarded by an unnecessarily high viscosity. The following theoretical discussion illustrates the fact, that the outer part of the lubricating oil film, when exposed to the hot gases during the firing stroke, protects the inner part of the film, which remains upon the cylinder walls. It is important, therefore, to quickly replace this outer film with fresh oil after the firing stroke, which demands a free-flowing, low-viscosity oil. The bearings are heated by conduction, through the metal of the connecting rods, etc., and the oil is compelled to work under high bearing temperatures. The viscosity of the oil should be sufficiently high to allow for a reduction, due to the bearing temperatures.

* **THEORETICAL DISCUSSION.**—Due to the high rubbing speeds of the piston, the period of time during which the lubricating film is exposed to the high temperatures of the firing stroke is very short.† The maximum temperatures usually met with in the cylinders of internal-combustion engines are usually about 2700° Fahr. This is the maximum temperature for the cylinder gases, and the temperature range will probably run as low as 250° Fahr., thus giving a mean temperature of the gases for the complete cycle of about 950° Fahr.

A film of petroleum oil, if exposed to a high temperature as described above, will not be instantly burnt, but will require that it be exposed to this high temperature for an appreciable length of time before it will be destroyed. It must, therefore, be assumed, that in the cylinders of these engines the high speeds and loss of heat in its transmission to the lubricating film will result in only a partial destruction of the lubricating film. There will be, therefore, a partially destroyed film of lubricant remaining upon the walls of the cylinders after the firing stroke has been expended. It is the heat conditions, to which this remaining film is exposed, that determine the severest requirements made on the lubricant, because this

* See index for Airplane Motor Lubrication data.

† NOTE. At the speed of 1600 R. P. M., the total time of 0.06 of a second is left for the oil film to be exposed to the burning.

film remains on the walls of the cylinder, which are hot, for a longer time than the outer film is exposed to the hot gases. While the cylinder walls are at a lower temperature than the hot gases, the increased time of exposure of the inner film to their heat causes the lubricating film as a whole to be attacked on the hot gas side by high temperatures for a short period of time, and, on the cylinder wall side, by lower temperatures for a longer period of time.

The value of the outer film as a heat-protecting blanket for the inner film may be relatively compared as follows: In a paper read before the Institute of Naval Architects in England, it was stated that "a film of lubricant one one-hundredth of an inch thick, a layer of boiler scale one-tenth of an inch thick, and a steel boiler plate 10 inches thick, offer equal resistance to the passage of heat."

In Bulletin No. 18 of the Bureau of Mines, on the subject of "The Transmission of Heat Into Steam Boilers," considerable data have been obtained, bearing upon the losses in heat between the moving gases in a boiler and the boiling water. These results are of value in this investigation, because in many ways the conditions are the same.

The following data are taken from this Bulletin:

The largest loss in the transmission of heat from the hot gases to the boiler water occurs in its transmission from the hot gases to the dry surface of the boiler tubes. The boiler tubes are, of course, covered with a layer of soot, then comes the metal, then the boiler scale, and last the water. The estimated, or figured, losses, as outlined in the above-mentioned Bulletin, are as follows:

Initial temperature of the gases, 2500° Fahr.

The temperature of the gases escaping to the stack is 600° Fahr. Then the average temperature of the moving gases would be

$$\frac{2500 + 600}{2} = 1550° \text{ Fahr.}$$

There were found to be the following temperature drops:

	Degrees Fahr.	Per cent.
From the hot gases (moving) to the soot surface.	1047	67.60
Through the soot layer	65	4.18
Through the boiler tube	13	.84
Through the boiler scale	65	4.19
From the scale to the water	10	.64
The resulting temperature of the boiler water	350	22.55
	1550	100.00

The clearance between the piston and the walls of an internal-combustion engine cylinder, varies from about 0.001 to 0.01 of an inch. The piston rings are fitted so closely that there is only a very thin film of oil permissible between them and the cylinder walls, and, at the temperatures reached here, all oils, whether originally light or heavy, will have about the same film thickness. It may, therefore, be assumed, that the heat-resisting value of the oil film in the engine cylinders and that of the soot covering in the above-described boiler will be about the same for all motor-cylinder oils. Knowing the average temperatures of the gases in the cylinders, it is possible to estimate the temperatures to which the inner lubricating film is exposed, as previously explained, by assuming the same

ratio of heat losses as those outlined in the results of the boiler investigation.

Referring to Fig. 3, Sec. 10y, which illustrates the path of the heat transfer from the gases to the cooling water of an engine cylinder:

	Per cent.	Degrees Fahr.
In passing from G to F^2	67.60	642.00
In passing through F^2	4.18	39.83
In passing through F^1	4.18	39.83
In passing through C	.84	7.97
In passing from C to W	.64	6.47
Transmitted to the water	22.55	213.90
		950.00

The cooling water is boiling, indicating severe conditions.

It is shown by the above table that with worst working conditions, but with efficient renewal of the outer protecting film:

The gas side of the "*inner lubricating film*" is exposed to only:

$950° - 642° - 39.83° = 268.17°$ Fahr., which is well within the flashing point of any oil.

The "*cylinder wall side*" of the inner film is exposed to:

$950 - 642 - 39.83 - 39.83 = 228.34°$ Fahr., so that the continued exposure of the inner oil film to this surface will not destroy it, ***provided the viscosity of the oil at normal temperatures is low enough to permit the outer protecting film of oil to be renewed efficiently after each explosion stroke.***

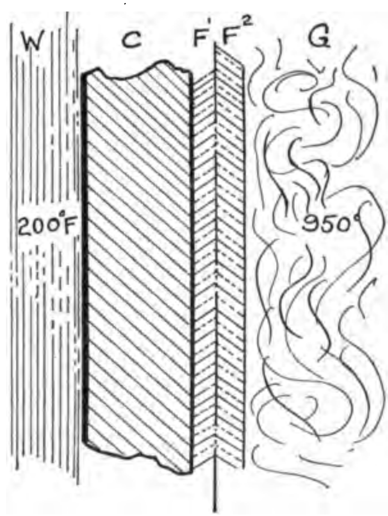


FIG. 3. SEC. 10y.—Sectional view of cylinder wall, illustrating temperature fall between the gases and the cooling water of an internal-combustion engine.

Summing up the results: It is evident from the above, that oils which are abnormally high in viscosity at normal temperatures will not give satisfactory lubrication in the cylinders of internal-combustion engines, because their viscosity cannot be reduced quickly enough, by the heat of the moving parts, to enable them to have a sufficiently low viscosity to form a quick-spreading film, which is entirely dependent upon the mechanical spreading action of the piston.

It is also evident that high viscosity oils will add an unnecessary friction load to the piston.

It is also shown that it is the heat-resisting properties of the outer film that permit any lubrication for the exhaust stroke of the piston, in that, at the first shock of exposure to the explosion heats, this film must burn slowly enough to protect the inner film, until the hot gases have begun to move fast enough to produce the large drop in the transmission of the heat, that will then occur.

EFFECT OF CARBURETION ON LUBRICATION.—Complete carburetion, or vaporization of the fuel, has a great bearing upon the efficiency of cylinder lubrication. The ideal condition is high initial pressure and very early complete combustion, approaching a gunpowder explosion. In a condition such as this, the maximum temperature is obtained when the piston completely, or nearly, covers the oil film on the cylinder walls, and the film is not exposed to the highest temperatures. If the fuel is not completely vaporized and thoroughly mixed with the proper proportion of air, slow burning occurs, and the oil film is exposed for a longer time to severe temperature conditions, as the piston moving downward uncovers the oil while combustion is still occurring. A retarded spark has the same effect as slow burning, as far as the oil film is concerned.

When considering oil dilution by the fuel, it must be appreciated that during the suction and compression strokes, the lubricant on the cylinder walls is in contact with the "air-and-fuel" mixture. The oil may absorb part of the fuel and then drip from the cylinder walls into the crankcase.

GAS AND OIL ENGINES AND COMPOUNDED OILS.—(Wells and Southcombe, *Journal Soc. Chemical Industry,* Vol. xxxix, No. 5, pp. 51T-60T): Messrs. Wells and Southcombe state: "The addition of cocoanut oil to a mineral oil gave best results. Refined rape oil or other fatty oil was also used in conjunction with cocoanut oil to the extent of about 5 per cent. of each; that is, about 10 per cent. of fatty oil, 90 per cent. mineral oil. Especially on large horizontal units, such a compounded oil was deemed essential. For smaller units smaller proportions down to 5 per cent. total fatty oil to 95 per cent. mineral oil, though some small units apparently required heavily compounded oils.

"For oil engines compounded oils, and for some types straight fatty oils, such as olive oil, have been considered essential. For several types * * * a compound of one-third refined rape oil to two-thirds mineral oil has been used. That oil has been superseded by an oil with a slightly higher percentage of fatty acid than the average "germ process" (a patented process involving the use of one or more fatty or other acids with one or more mineral oils, the fatty acids being in small percentages and to replace fatty oils for compounding lubricating oils), with success. * * * As an index that compounded oils are still considered advisable for many gas and oil engines, one of the British Government's department specifications for lubricating oil for internal-combustion engines, stipulates the use of '10 per cent. lard oil to 90 per cent. mineral oil, the acidity not to exceed 0.05 per cent. *KOH* (*i.e.,* about 0.25 per cent. as oleic acid)."

LUBRICATORS

AIR-SPRAY, FORCED-FEED, CYLINDER LUBRICATION.—When an automatic cylinder lubricator, such as is shown in Fig. 4 Sec. 10y, on steam engine cylinder lubrication, is used to supply cylinder

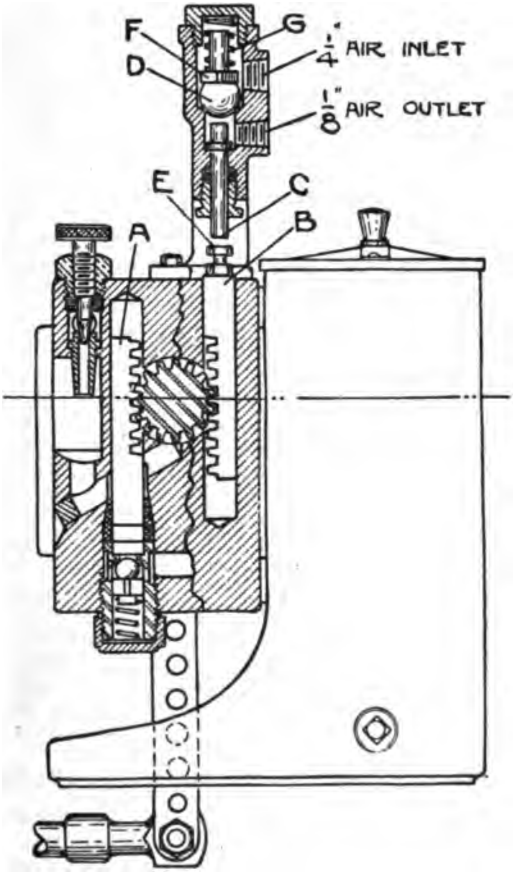


FIG. 4. SEC. 10y.—Air spray attached to Richardson lubricator.

oil to gas engine cylinders, a device such as is shown in Fig. 5, Sec. 10y, is sometimes used. This device is manufactured by the Richardson-Phenix Co.

As is shown in the figure, it consists of a small automatic air valve, mounted on top of the lubricator and connected to a source of compressed air. As the plungers come down and force the oil out, through the terminal check valves, a plunger in the lubricator opens the air valve and

supplies a puff of compressed air, which atomizes the oil at the instant it is delivered into the cylinder.

FORCED-FEED CYLINDER LUBRICATION, LARGE GAS ENGINES.—When a forced-feed lubricator of the type described in the preceding section is used with large gas engines, the lubricator has a divided shaft. The driving levers being set 90° apart, with one-half of the feeds delivering oil at one end of the stroke and the other half at the other end of the stroke. With an eight-feed lubricator, two feeds at each end feed through check valves through the water-jacket into the cylinder. One feed is connected to each of the exhaust valves and one feed each to the piston and tail-rod packing glands. This, of course, refers to a horizontal type of engine.

* **CYLINDER DEPOSITS.**—All petroleum oils are hydrocarbons. Petroleum lubricating oils consist of about 85 per cent. carbon and about 15 per cent. of hydrogen. Therefore, in any internal-combustion engine cylinder, when the outer film of lubricant has been partially, or entirely, destroyed by the heats of the firing stroke, there will necessarily be some

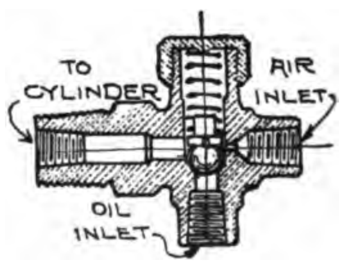


FIG. 5. SEC. 10y.—Terminal check valves.

carbon liberated. The carbon, however, should be of such a nature that it will be expelled from the cylinder along with the exhaust.

If the vaporization of the outer oil film leaves a gummy residue, the liberated carbon will stick to it and remain in the cylinder. Dust, from the air mixed with the incoming fuel, will be absorbed by this residue, and gradually a thick deposit will be built up, which soon is baked into a hard, so-called "carbon deposit."

These deposits are usually produced by the following causes:

(*a*) Feeding an excess of oil.

(*b*) Leaky piston rings.

(*c*) Too viscous an oil used.

There is no petroleum lubricating oil that is free from carbon, although many manufacturers have made this claim through their salesmen and advertising.

A troublesome carbon deposit and heavy exhaust smoke will also result when too light oil is used, the oil being sucked past the piston rings into the explosion chamber.

When heavy carbon deposits occur, the quality of the gasoline should be investigated. Poorly refined gasolines contain deposit-forming com-

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* See index.

pounds. To test the gasoline, a burn test may be made. In this test, a small porcelain crucible is filled with about 30 c.c. of the gasoline and the gasoline ignited and allowed to burn to the end. The purity of the gasoline may then be judged by the character of the residue left on the walls and bottom of the crucible. Only a small amount of lampblack left on the walls and a clean bottom indicates that the gasoline is good. But a heavy deposit on the walls of the crucible and a tarry black deposit on the bottom indicates poor gasoline. An oily residue may be left if the deposit is very bad.

OXIDATION OF AUTOMOBILE CYLINDER OILS.—In a recent paper, by Mr. C. E. Waters, Associate Chemist of the Bureau of Standards, Washington, D. C., on the subject of "Data on the Oxidation of Automobile Cylinder Oils," the following conclusions were stated:

The so-called "carbonization" of automobile cylinder oils is due only to a very limited extent, if at all, to "cracking," but is caused by oxidation and subsequent polymerization.

When an oil is carbonized in the laboratory, a brown coating is formed on the walls of the flask, which is usually called "varnish," and from the large mass of data obtained, the statement is verified, that there is no regularity in the amount of the varnish formed, and no connection between this and the amount of precipitate thrown down by petroleum ether.

It is shown that the carbonization value of an oil is independent of the flash-and fire-points and of the evaporation loss on heating.

It was found that the greater the carbonization value of an oil at first, the more rapidly did it increase as the temperature was raised or the time of heating was extended.

An oil which has a low carbonization value when heated to 250°, for two or three hours, and an oil showing a higher value under the same conditions, will be farther apart as the conditions become more severe.

Mr. Waters suggests that it is unnecessary to heat oils in carbonization tests for as long a time as is usually prescribed, and recommends that the tests run only two and one-half hours.

THE EFFECT OF ADDED FATTY AND OTHER OILS UPON CARBONIZATION OF MINERAL OILS.—(Technologic Paper No. 4, Bureau of Standards, C. E. Waters): "Tests were reported in this bulletin to determine the amount of carbonization of a straight mineral oil and of the same oil with known amounts of other constituents, such as lard oil, resin oil, tallow, etc., added. * * * The mineral oil selected was an engine oil flashing at 140° in the Pensky-Martens closed cup tester. Seven samples, as follows, were tested:

1. The straight mineral oil. When 10 grains, diluted with 50 c.c. of petroleum ether, were allowed to stand overnight, it yielded only traces of precipitate. These proportions of oil and solvent are the same as those adopted in the carbonization tests.

2. The mineral oil heated with Ivory soap shavings for several hours in a closed flask on a steam bath. It was allowed to stand overnight and then filtered. After standing several weeks in a closed bottle it set to a sort of jelly, but became perfectly fluid on shaking and remained so. Very little soap was in solution, for it gave only 0.03 per cent. of ash.

3. The mineral oil saturated with resin in the same way as with the soap. It yielded only 0.03 per cent. of matter insoluble in petroleum ether.

4. A 10 per cent. solution of resin oil in mineral oil.

5. A 10 per cent. solution of rapeseed oil in mineral oil.

6. A 10 per cent. solution of lard oil in mineral oil.

7. A 5 per cent. solution of tallow in mineral oil. It yielded 0.20 per cent. of matter insoluble in petroleum ether.

"As shown by an earlier report (Bull. Bureau of Stds. No. 7), the insoluble precipitate is an oxidation product. It ought, therefore, to vary in amount with the time of heating and with the surface of oil exposed to the air. * * * For each determination 10 grain samples were introduced into flasks (65 mm. at widest part and the bore of the neck 21 mm., capacity 150 c.c.), which were heated to 250° for five hours in an air bath. * * * After cooling, the flasks were wiped off and weighed to determine loss by volatilization. Then 50 c.c. of petroleum ether was added. The flasks were corked and shaken with a gentle, rotary motion until the thick residue went into solution as completely as possible, afterwards allowed to stand 24 hours. * * * The insoluble matter was then filtered off on Gooch crucibles prepared with a disc of "blue ribbon" paper, covered with a fairly thick felt of fine asbestos. The residue on the filter was washed with petroleum ether and dried at 93°–95° before weighing. * * * The flasks were thoroughly rinsed with petroleum ether to remove all oil and precipitate. They were also heated to same temperature and weighed to determine the amount of varnish-like coating on the walls."

Other samples tested were.

8. Straight mineral oil purporting to be same as No. 1.

9. Mineral oil, to every 10 gram of which was added 0.25 g. of Syrian asphalt dissolved in 25 c.c. of xylene. The solution was always added after the oil was weighed, and the solvent driven off by heating on the steam bath, at the same time blowing a gentle current of air into the flask. Before heating, petroleum ether threw out 1.35 per cent. of insoluble.

10. Mineral oil, to every 10 gram of which, 0.01 gram of sulphur dissolved in 1 c.c. of xylene was added. In this case the solvent was not driven off before heating.

11. A 10 per cent. solution of 55° paraffin in mineral oil. This could be poured about as well as a heavy cylinder oil.

12. A 10 per cent. solution of linseed oil in mineral oil.

13. Mineral oil and soap. To every 10 grams of the oil was added, before heating, 0.50 gram of finely powdered Ivory soap, dried at 100°–105°.

14. Mineral oil oxidized by combined action of air and sunlight.

15. Mixture of mineral oil with "Kahlbaum" ferric oxide. In each 10 grams of the mixture there was 0.086 gram of oxide.

16. Mineral oil oxidized in flasks.

Mr. Waters gives the following points in his conclusions: "Comparing results of Nos. 1 to 7, it is evident that with the exception of adding resin, the admixture of other oils to the mineral oil has caused a greater or less diminution in the amount of insoluble and total residue. The same is also true of the 'varnish.' * * * Considering Nos. 8 to 16, the addition of asphalt increases the percentage of insoluble. The addition of sulphur caused no marked difference. The same is true of the

addition of paraffin. Linseed oil enormously increased the amount of total residue. The oil exposed to action of sunlight and air in No. 16 was more completely oxidized than for No. 14, and is reflected in the tests.

Table of Average Results of the Tests as Above

Sample	Contains	All values included "Varnish"	All values included Insoluble	All values included Total residue	Aberrant values omitted "Varnish"	Aberrant values omitted Insoluble	Aberrant values omitted Total residue
1	Mineral Oil	0.33	2.26	2.59	0.32	2.21	2.53
2	Soap	0.11	2.06	2.17	0.13	1.93	2.06
3	Resin	0.27	2.25	2.52	0.24	2.30	2.54
4	Resin Oil	0.21	1.90	2.11	0.17	1.90	2.07
5	Rapeseed Oil	1.37	0.01	1.38	1.42	0.01	1.43
6	Lard Oil	0.09	0.40	0.49	0.05	0.31	0.36
7	Tallow	0.11	1.37	1.48	0.09	1.37	1.46
8	Mineral Oil	0.35	2.51	2.86	0.35	2.60	2.95
9	Asphalt	0.29	4.66	4.95	0.29	4.66	4.95
10	Sulphur	0.37	2.52	2.89	0.31	2.59	2.90
11	Paraffin	0.30	2.70	3.00	0.39	2.44	2.83
12	Linseed Oil	6.30	0.02	6.32	6.38	0.02	6.40
13							
14	Oxidized Mineral Oil	0.28	6.00	6.28	0.30	5.82	6.12
15	Fe_2O_3	1.02	6.50	7.52			
16	Oxidized Mineral Oil	0.31	7.02	7.33	0.31	7.32	7.63

GENERAL DATA.—Engines using gasoline do not usually get as hot as those using kerosene or distillate.

Engines operating satisfactorily on medium motor oil, when using gasoline, will give better results with heavy or extra heavy oil, when the fuel is changed to kerosene.

Full forced-feed systems can satisfactorily use heavier oils than can the splash-system types.

Geared oil pumps have been found to give better results. They fail, however, due to leakage, both internal and external, and are often undersized for the work required.

Truck motors require medium, and tractor engines heavy, or special heavy, oils. Small tractor engines, which do not have as much piston clearance and do not get so hot as the large engines, may use lighter oil.

It is very important that sufficient screening area be provided, particularly for heavy duty service.

The crank-case oil in tractor engines is often diluted badly, due to leakage past the piston rings. Generally gasoline that has leaked by will eventually evaporate, but the kerosene will stay.

It has been found by certain authorities that two weeks' service with kerosene fuel will reduce the engine power 20 per cent. unless the crank-case oil is completely removed and replaced with good fresh oil.

ENGINE TESTS

LUBRICATING TESTS — INTERNAL-COMBUSTION ENGINES.—The report of a lubricating test of an internal-combustion engine should follow the following general outline, and be grouped under the headings as indicated:

(a) DESCRIPTION OF ENGINE

The make, type, peculiarities of design, type of lubricating system (forced feed, splash feed, or combination), size of engine, kind of duty for which the engine is used.

(b) DATA ON ENGINE CONDITION

The ignition system, carburetors, or fuel injectors, valves, cylinders, bearings, lubricating system, and individual peculiarities of the engine should be examined and the conditions noted.

(c) PREPARING FOR THE TEST

Before starting the test, the bearings and crank-case should be thoroughly cleaned out with kerosene, which will give better results than can be obtained with gasoline. Carbon deposits in the cylinder head, piston rings, etc., should be removed.

The oil to be tested is then introduced into the engine, and the engine is run at least an hour, preferably more, so that the new oil can be thoroughly worked into the bearings and cylinders.

(d) TESTING

The length of time of test must be determined from the local conditions. Care must be taken not to make the test too short. The usual time for stationary engine tests is from ten to thirty hours. On small engines this period may be reduced to not less than five hours. Automobile engines, on block test, should be run at least six to ten hours. Road tests on tractor and automobile engines should be for a distance of about 400 to 500 miles for automobile engines, and 75 to 100 miles for tractor engines.

A record of the total time the engine is running should be kept. This record should show the "*periods of idle running and loaded running.*" All *stops and starts* must be noted in their proper place on the chart. This is due to the fact that the proportion of fuel is higher when the engine is picking up than when running at steady speed. Also the cylinder pressures are higher and combustion poorer. This would tend to waste some of the pressure, and also some of the fuel will leak past the rings and get into the crank-case.

At regular intervals the "*revolutions per minute*" of the engine should be taken.

The "*load on the engine*" should be noted. This can best be measured by means of a prony brake (see index). If the test is run under shop conditions and no prony brake or dynamometer is available, either the electrical output may be measured, if the engine is connected to a dynamo, or if to shafting, the number of machines being driven at each time interval should be noted. One of the main things to be determined by the

test is the behavior of the lubricant under full-load conditions, as it might give good lubrication under low speed or no load, but fall down under full-load conditions.

The "*fuel consumption*" for the full period of the test must be measured and the record inserted in the proper place on the data sheet to correspond with the load conditions and speed at that time.

The best method of getting the fuel consumption is to place a small tank on a platform scales. The scales should be corrected to allow for the weight of the tank and fuel line. Readings can then be made at the regular intervals of time when the speed of the engine is taken, the difference in the weights will give the full consumption, which may then be figured on the basis of pounds per horse-power. If the small tank, as described, cannot be used, a measurement of the tank should be made and the gallonage for each inch of height figured out. Then the level of fuel in the tank can be taken and the fuel consumption calculated at regular intervals, as above described.

The "*temperature of the cooling water*" should be taken at regular intervals. This should be taken both for the inlet and outlet water. The temperature of the cooling water is a direct indication of the temperature of the cylinder walls and also has an influence upon the temperatures met with in the crank-case. These temperatures affect the viscosity of the oil and the piston-sealing properties of the oil. The high temperatures of the engine parts also affect the rate of consumption of oil.

The "*consumption of lubricating oil.*" An accurate measurement should be made at regular intervals, to correspond with the other readings of the rate of consumption of the lubricating oil. This can best be done by feeding the oil from a graduated vessel, graduated to read direct in cubic centimetres, although for practical shop tests, the oil fed to the lubricator and the number of drops per minute may be used to determine the consumption of oil.

At regular intervals and at the end of the test "*samples of oil taken from the used oil* in the crank-case should be preserved for laboratory test, to determine the wearing qualities of the lubricant.

The "*temperature of the bearings*" should be noted from time to time.

The "*room temperatures*" should also be noted from time to time, to be used in connection with the other test temperatures taken.

The "*weather conditions*" should be noted at various times during the tests, as these conditions affect the operation of the engine. For instance, the engine will run on less fuel at night when the air is heavy as compared with the time when the sun is out. Cloudy days and barometric pressures also affect the engine operation. The best results can be obtained by comparing two oils under the same weather conditions.

After the engine has been stopped at the end of the test, the cylinder heads and piston heads should be "*examined for carbon deposits.*" Samples of the carbon deposit should be taken and the cylinder from which it is obtained on the container. The quantity of the deposits should be obtained and their nature, viz.: Whether light fluffy, powdery, etc., or sticky or hard.

The condition of the "*spark plugs and ignition*" should be noted

NOTES. A poor lubricant will cause the engine to drag. This will be indicated by an effect upon the speed. A rough estimate of the compara-

tive condition of the oil film can be obtained by the following method. A pack of tissue-paper sheets or cigarette papers is fastened to a wooden block. The face of the block is cut to circular form to correspond with the radius of the cylinder walls, and the papers are bound tightly to the block, which is then held with a uniform pressure against the cylinder wall for five minutes and the number of thicknesses of paper penetrated by the oil is a comparative indication of the film thickness, when compared to the results obtained for the same engine with another oil under the same paper, time and pressure conditions.

INTERNAL-COMBUSTION ENGINES; LUBRICATING AND FUEL TESTS ON; VARIABLE FACTORS AFFECTED.—In a report presented in connection with airplane lubrication and fuel testing by the Equipment Division, Signal Corps, U. S. Army, the following comments are made, with reference to the various factors met with in testing: In testing work on a large scale, and under high-speed conditions, inconsistencies are bound to show on the record. Theoretically, certain effects should follow certain causes; practically, on this kind of testing work, some variable factor operates at times, and the curve does not always act as it should. To compensate for these variables, and average all conditions, it is necessary to make many observations, and over a considerable period of time, and to use the same operators and instruments on the same station, and everything possible that good judgment could dictate. * * * The variable factor, due to carburetion, has affected results more than any one item. Carburetion, of course, is due to a number of features not readily controlled: The results of variation in carburetion is a difference in the amount of gasoline used, and a like difference in the amount escaping by the piston rings during compression stroke, and contaminating the lubricating oil. Power of the engine and temperature of the cylinders are likewise affected. It is impossible in a test of this nature, operating over a period necessary to complete the work, to absolutely control this feature of carburetion so as to eliminate any variation produced by this cause. * * * A certain amount of latitude must always be allowed * * * where samples of oil are sent to different laboratories, * * * and in the case of new oils for each test, where samples are duplicated, * * * in oils of the nature required for these engines there is always apt to be some slight difference, due to imperfect combining of light and heavy products, and the variation, which would be noted in the laboratory reading on the same oil, might be due to slight variation in the oil itself, even though the samples came from the same package.

HORSE-POWER

HORSE-POWER FORMULAS.—

$$\text{I. H. P. (Indicated Horse-power)} = \frac{\dfrac{L \times D}{T}}{33{,}000}$$

Where L = Mean effective pressure during the working stroke.
D = Length of the stroke in feet.
T = The time of one impulse, or the time of a complete cycle; that is, the time from one power stroke to the next power stroke.

$T = \frac{1}{N}$ where N is the number of power strokes per minute.

N = For a two-cycle engine the number of R. P .M.

N = For a four-cycle engine the number of $\frac{\text{R. P. M.}}{2}$

The above formula applies to the work done by one cylinder, and applies only to a single-acting engine; that is, one in which the propelling force acts only on one side of the piston. Practically all internal-combustion engines are single acting.

For a multiple-cylinder engine, the total power developed by the engine is the product of the power developed by one cylinder as obtained by the formula above, multiplied by the number of cylinders. The power developed by any single-acting, single- or multiple-cylinder engine, may be obtained by determining the factors called for in the following formula and carrying out the calculations:

$$\text{I. H. P. (for a single-acting engine)} = R \times \frac{P \times L \times A \times N}{33{,}000}$$

Where R = Number of cylinders.
N = Number of power impulses or explosions per minute.
P = Mean effective pressure in pounds per square inch, obtained by taking indicator diagrams and obtaining their mean height, to scale.
L = Length of the stroke in feet.
A = Area of the piston in square inches.

For two-cycle engines, N equals the number of revolutions made per minute; and for four-cycle engines, N equals the number of revolutions made per minute divided by two.

HORSE-POWER CALCULATIONS.—For purposes of illustration the following typical example is worked out from actual figures:

(*a*) Engine has six cylinders.
(*b*) Makes 1800 R. P. M.
(*c*) The mean effective pressure obtained by the indicator is 73 pounds per square inch.
(*d*) Stroke is 5 1/4 inches.
(*e*) Diameter of cylinder, or bore, is 3 1/4 inches.
(*f*) Four-cycle engine.

According to the formula:

$$I.H.P. = R \times \frac{P \times L \times A \times N}{33{,}000}$$

$$= 6 \times \frac{73 \times \frac{5.25}{12} \times \frac{3.14 \times \overline{3.25}^2}{4} \times \frac{1800}{2}}{33{,}000}$$

$$= 6 \times \frac{73 \times .438 \times 8.27 \times 900}{33{,}000}$$

$$= 43.3\ H.P.$$

SOCIETY OF AUTOMOBILE ENGINEERS' HORSE-POWER FORMULA.—This formula is known as the S. A. E. formula and is an arbitrary formula, which will give a fair degree of accuracy only when the speed of the engine is about 760 R. P. M.

The S. A. E. formula is as follows:

$$S.\ A.\ E.\ (H.\ P.) = \frac{D^2 \times R}{2.5} \text{ (for four-cycle engines).}$$

Where D = Diameter of the cylinder bore.
R = Number of cylinders.

(or) $$H.\ P. = \frac{D^2 \times R}{1.5} \text{ (for two-cycle engines).}$$

FORM 1 HP

SECTION No.

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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SECTION 10z

INSECT SPRAYS

INSECT SPRAY FOR PLANTS AND TREES.—Emulsions made with soluble oils are sometimes used as sprays for destroying insects and plant destroyers. They are particularly used for spraying peach trees, or other trees containing a scale of a similar nature. There are two classes of these oils; namely, the sulphonated and the soluble oils. A sulphonated oil is an oil treated with sulphuric acid, and the excess acid washed out, and only that which combined chemically with the glyceride permitted to remain therein. After this operation, the oil is then neutralized with an alkali, either soda or ammonia, or a combination. An oil of this nature, when properly sulphonated, should make a solution in water having a slight opalescence. Soluble oils can be made using resin oil, saponified with borax, cooked until the water is evaporated. (Usually over steam, because of resin fumes.) Then this will take up mineral oil (about 2 lbs. to gallon borax to resin oil; vary from 10–12 parts, 28° paraffin oil). The described soluble oil would be known as a resin-base oil. Soluble oil can also be made from red oil. Saponify oleic acid (elaine), with water and soda (32°–40°). Cook up red oil to soap and clarify with wood alcohol, amount depending upon acid strength of oleic acid. (To bring up acid strength, use sulphuric or acetic acid.)

The terrapin scale has an outside epiderm. The San José scale has an armored scale, with a wax covering underneath. The sprays used must work in underneath these coverings. They must fill the sucking part of the insect, and in this way prevent them from making further scale. The oil used for this purpose, when dissolved in water, must be practically neutral, and should have no detrimental effect upon the tree or foliage, providing it is not used excessively.

For plant lice and sucking insects, and for other general insectide purposes, a kerosene emulsion may be used. This may be made by melting 6.5 per cent. by weight of soft corn oil soap that is free from silicate of soda with about 4.5 per cent. of hot water in a steam-jacketed vessel, or by direct fire. To this is added 23 per cent. by weight of kerosene oil, adding it in small amounts while stirring. When the mixture begins to boil, the kettle is removed from the fire and stirred for about a half hour. The milky emulsion obtained may show some separation, which will disappear on again stirring. This emulsion is then used as a spray with about 20 parts of water, when applied to plants or trees.

Another product used to make kerosene emulsions is whale oil soap. Whale oil soap may be made by mixing with caustic soda and water a good grade of southern whale oil, and then gradually adding about 4 per cent. of kerosene.

For making the insect emulsion, the whale oil soap is dissolved in hot water. Then an amount of carbolic acid is added, and the mixture brought to a boil. After which it is removed from the fire and kerosene added. This solution is applied diluted with about 20 parts of water. It is used for eliminating the Citrus Mealy Bug and similar insects, which are coated with a cotton- or wool-like covering. The emulsion should be applied with a power sprayer.

Pure kerosene has been used to spray dormant trees badly infested with the San José and other scales. Treatments of pure kerosene should be applied through a nozzle with a very fine aperture. Applications should only be made on bright days.

In California a crude oil emulsion at 12 per cent. strength is used as a dormant spray for control of the European fruit lecanium and the European pear scale. In preparation of this emulsion a natural oil (asphalt base) direct from the wells, ranging 16° to 22° Baumé should be used. Fish-oil soap may be used as an emulsifier. An emulsion may be of 20 pounds fish-oil soap, 4 pounds lye, 24 gallons western crude oil (16°-22° B.) and 176 gallons of water.

In the East an oil known as "insecticide oil," having a gravity of 43° to 45° B., may be used as an emulsion, the crude petroleum being substituted for kerosene as previously described.

For pear thrips, a combination of 3 per cent. distillate oil emulsion and nicotine sulphate (40 per cent.), at the rate of 1 pint of the latter to 200 gallons of the former, is used. Distillate oil (raw), 30°-34° B. is used.

SECTION 10aa
MARINE ENGINES AND MARINE OILS

MARINE STEAM CYLINDERS

The conditions governing the lubricating requirements of marine engines are different in many respects from those governing the lubrication of stationary engines.

Reciprocating engines used in the marine trade are of the vertical type, in which type of engine the weight of the piston is not dragged on the bottom of the cylinder, as is the case in the horizontal type of engine. As a result, there is less frictional wear in the cylinders of marine engines and consequently less necessity for a cylinder lubricant.

Steamers plying in the off-shore, or salt-water trade, are provided with surface condensers, to condense the exhaust steam from the engine, and thus economize the fresh water suitable for boiler use. The condensed steam is pumped by the feed pump back to the boilers, to be made into steam again. If cylinder oil is used in the cylinders of the engine, it will be carried out with the exhaust steam into the condenser, causing poor efficiency. Some of the oil will be carried by the feed-water into the boilers, causing trouble due to "bagged plates" and other causes. For this reason, and also due to the fact that little lubrication is required by the cylinders, no oil should be used in them.*

For boats plying in fresh water, or in the coastwise trade, a little cylinder oil fed to the cylinders will prevent rusting troubles and reduce the friction load.

The piston rods of all types of vessels should be occasionally swabbed with a good quality of steam-refined cylinder stock oil. For this purpose, an excellent oil would have the following general specifications:

(*a*) About 150° Vis. at 212° Fahr.
(*b*) Unfiltered
(*c*) Flash over 500° Fahr.
(*d*) May, or may not, have 5 to 10 per cent. acidless tallow oil compound.

WATER POLISH.—The cylinders of marine engines, in which no oil is used, take on a so-called "water polish."

This "water polish" is a thin, hard skin, formed upon the surfaces of contact, when the condensation water furnishes the only lubrication. It gives a very smooth, satisfactory surface, but if the ship is in port for some time, with her engines standing still, this surface is quickly lost, and unless protected by a coating of cylinder oil or vaseline, the cylinder surfaces will soon rust. It is, therefore, advisable to feed cylinder oil to the cylinders of a ship just before she docks.

Practically no ships in the United States Navy use cylinder oil direct to the cylinders, or valves, either in the main engines or in the auxiliaries, ventilating, or reversing engines. Swabbing oil is used, however, on the piston rods, to prevent undue wear in the stuffing-box packing.

* NOTE. See page 762 for superheated steam conditions.

In some marine engines, " D " slide valves of the ordinary or double-ported type are used. These valves, if heavy, are usually connected at the top to a balance piston. The "balance chamber" is practically an inverted dashpot, with the bottom exposed to the atmosphere. The "clearance" on the top of the balance piston is connected to the condenser, in which a vacuum of about 26 inches is carried. The dead weight of the valve is thus removed from the eccentrics and link block. The balance cylinder should be occasionally swabbed with cylinder oil.

TUG BOATS.—Tug boats, ferries, and other craft, which have fresh-water supplies available, usually run their engines non-condensing and use cylinder oil in their cylinders.

A satisfactory oil for the engines of these boats, using saturated steam, would have the following general specifications:

(*a*) Viscosity at 212° Fahr. ... 140 to 150.
(*b*) Flash .... 525° to 550° Fahr.
(*c*) Compounded with .... 5 per cent. acidless tallow oil.

SUPERHEATED STEAM.—Marine engines, using superheated steam, should be supplied with cylinder oil, because there is very little water of condensation in the high and intermediate cylinders to furnish lubrication.

These ships usually have a steam pressure of about 250 to 275 pounds per square inch at the valve chest. This would give a steam temperature for 265 pounds of 411° Fahr. The steam is passed through superheaters and given about 50° to 75° superheat, making a maximum temperature at the valve chest of 486° Fahr. Therefore, an oil of the following general specifications will give satisfactory lubrication:

(*a*) Flash over 600° Fahr.
(*b*) Viscosity 275 to 320 at 212° Fahr.
(*c*) No compound.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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BEARING AND SLIDE LUBRICATION

LUBRICATION OF NAVAL ENGINES.—In the navy, ships having reciprocating engines of the latest type are lubricated in the following manner: All working parts of main engines, except the "valve links" and "valve stem guides," which are efficiently lubricated by combination sight and wick feed oil-distributing boxes located on the engine, are lubricated by forced-feed lubrication through a suitable system.

The "cross-head guides" are provided with both gravity and forced-feed systems.

LUBRICATION OF MARINE ENGINE BEARINGS.—The main shaft bearings are usually cored and provided with pipes, so that water may be circulated through the bearings to keep them cool.

THRUST BEARINGS.—The most important bearing on a ship is the "thrust bearing." This bearing is the hardest to keep cool. The whole thrust, or power, of the engine that is available to propel the ship is exerted against this bearing.

The thrust bearing is secured to the frame of the ship, "abaft" the engine. It consists of a metal case and cap, which contains a number of babbitt-faced, horseshoe-shaped yokes, which are separated by open spaces. The shaft is equipped with a number of collars, which fit into the spaces between the yokes of the bearing, and the faces of these collars bear against the babbitted faces of the "yokes."

The top of each yoke is equipped with an oil pocket, and an oil feed leads from it to the wearing surfaces. A small piece of wool waste is usually kept in this pocket, or "oil boat," as it is called, to regulate the feed of the oil.

The lower part of the bearing is so arranged as to form an oil reservoir, which will contain a supply of oil, or oil and water, so that the collars will dip their lower parts into the oil and carry it up to the bearing surfaces. While the use of water is an old custom, it really defeats the very purposes for which it is intended, as is noted in the paragraph below.

TUNNEL BEARINGS.—For the lubrication of the shaft bearings, or tunnel bearings, the usual past practice has been to use a so-called "tunnel-bearing grease." This grease is made up in a block form, so dimensioned that it can be sliced into small blocks, which are put in the grease pockets on the bearings and allowed to rub against the shaft, thus greasing it.

In a successful installation no tunnel-bearing grease was used. The shaft was supported by bearings spaced 14 feet apart, the shaft was 13 1/4 inches in diameter. The bearings were designed to give a bearing pressure of 50 pounds per square inch. Two rings were supplied for each bearing. The bearings were lubricated with an oil having the following tests: 245 Vis. at 100° Fahr., Say.; P. B.

EFFECT OF WATER AND OIL MIXTURES ON THE EFFICIENCY OF LUBRICATION.—The curve shown in Fig. 1, Sec. 10aa, illustrates, from the results of actual tests, the effect on the friction of a bearing when it was lubricated with varying percentages of water and oil. The bearing was run at a thousand revolutions per minute and with

a constant bearing-cap pressure, until, at 30 per cent. of water in the mixture, the film broke and the bearing overheated, necessitating a decrease in the speed to 800 R. P. M. The temperature of the bearing cap was maintained at 150° Fahr.

The curve clearly shows that water mixed with oil and used for lubricating purposes increases the friction of the bearing, and should be a strong argument against this practice, except in extreme cases.

TURBINE-DRIVEN SHIPS.—On a turbine-propelled ship, the lubricating oil in the system should be circulated for at least 20 minutes to a half hour, through the bearings, after the turbines have been shut down. This will clear the bearings of any water, and thus prevent corrosion.

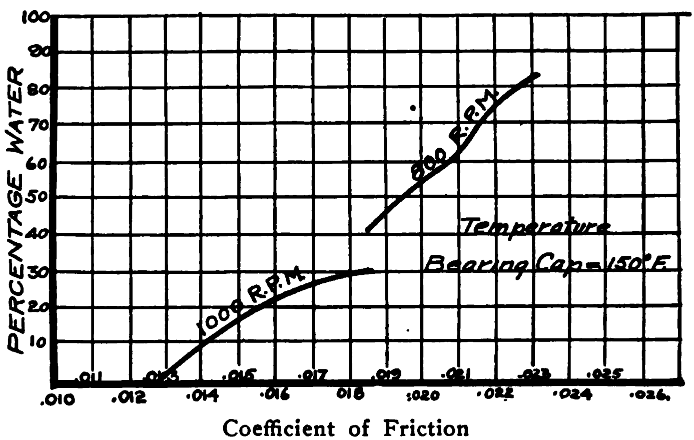

FIG. 1. SEC. 10aa.—Coefficient of friction. Curve showing the effect on the coefficient of friction produced by various mixtures of oil and water.

Very often corrosion, which is blamed on acid supposedly contained in the oil, is really caused by water which has been allowed to remain in the bearings. due to shutting down the oil pump too soon.

The lower part of the bearing acts as a settling tank in this case, allowing the water to separate from the oil and come into contact with the surfaces of the journals.

LUBRICATING SYSTEMS.—A typical naval torpedo boat lubricating system may be described as follows:

The engines are used up to 16 knots per hour, and then the turbines are used. The steam pressure is about 250 pounds. No cylinder oil is used.

Lubricating oil for the thrust bearings, turbines, and engines is supplied by a forced lubricating system. The course of the oil is from the bearings, to a settling tank, to the cooling tank, and then, under 10 pounds pressure, to the bearings.

The oil leaves the bearings at about 100° Fahr. and reënters them at about the temperature of the sea-water. The oil is cooled by passing it through pipes, surrounded with sea-water, while within the oil pipe is a smaller pipe through which water is also circulated, thus cooling the oil from both sides.

The propeller shaft is direct connected and turned at 600 R. P. M. (approximately) when running at full speed.

MARINE ENGINE OILS.—Marine engines are generally equipped with wick feeds, and are lubricated with a highly compounded engine oil, having a high viscosity and good "lathering" properties when in contact with water.

Blown rape-seed oil, or lard oil, is used to compound with mineral oil to manufacture marine engine oils, the object being to secure a good emulsification and lathering effect on the moist surfaces. This custom has been so firmly established in marine practice that it is very difficult to change it. There are, however, many straight mineral oils, particularly heavy paraffin oils, manufactured to-day that will give complete satisfaction for this class of work, staying on the rods even though considerable moisture is present.

Marine engine oils that are compounded with blown rape-seed oil should be examined as to their staple compound qualities. Due to the difference in gravities between petroleum oils and blown rape-seed oil, there is always a tendency for the rape-seed oil to separate out on standing, particularly in a warm place. Barrels containing this oil should be well rolled before they are opened and the contents removed, to insure a uniform percentage of the rape-seed oil throughout the mixture.

The following specifications give the general tests of typical marine engine oils:

Paraffin-base mineral oil:
- (*a*) Vis. at 100° Fahr.: 580 Say.
- (*b*) Gravity: 22.5° B.
- (*c*) Flash: 395° Fahr.
- (*d*) Compounded with 25 per cent. blown rape.

Asphalt-base mineral oil:
- (*a*) Vis. 700 at 100° Fahr.
- (*b*) Gravity: 18.5.
- (*c*) Flash: 350° Fahr.
- (*d*) Compounded with 15 per cent. rape.

Paraffin-base mineral oil:
- (*a*) Vis. at 100° Fahr: 350 Say.
- (*b*) Gravity: 23.5° B.
- (*c*) Flash: 470° Fahr.
- (*d*) Compounded with 15 per cent. Extra No. 1 Lard Oil.

Paraffin-base mineral oil:
- (*a*) Vis. at 100° Fahr.: 380.
- (*b*) Gravity: 23° B.
- (*c*) Flash: 470° Fahr.
- (*d*) No compound used.

Messrs. Wells and Southcombe, with reference to their "Germ process," report that marine bearing oils carrying 20 per cent. of fatty oil compound have been successfully replaced with an oil containing a comparatively small compound percentage of fatty acid in place of the fatty oil. Their patent relates that an emulsifying oil suitable for marine lubrication is produced by adding 1 per cent. of the acids obtained from rape oil or wool grease and the like to a viscous hydrocarbon oil.

WICK-FEEDS

WICK-FEEDS, STANDARD.—One of the largest operators of vessels uses the following schedule of wicks for wick-feeds:

For steaming 6 knots per hour	3 strands
For steaming 10 knots per hour	4 strands
For steaming 14 knots per hour	8 strands

When steaming 14 knots and over, an extra set of 10 strands is used for the crank-pins only.

COMPARISON OF THE AMOUNTS OF STRAIGHT MINERAL MARINE ENGINE OIL AND RAPE COMPOUNDED MARINE ENGINE OIL WHICH WILL BE FED BY A WICK-FEED UNDER NORMAL RUNNING TEMPERATURE.—A test was made to determine whether the amount of oil fed by a marine wick-feed would be increased, if a straight mineral engine oil were used instead of a rape compounded marine engine oil.

The amount of oil fed at ordinary temperature was, of course, greater with the straight mineral oil than with the compounded oil, but on a marine engine the oil box is usually fixed to the side of a steam cylinder, and the oil is kept at a high temperature. The temperature averages between 160° and 180° Fahr.

Fig. 2, Sec. 10aa, shows the apparatus used in making the test. *A* is the oil-containing box. *B* is an electric heating coil, which kept the oil at a temperature of 170° Fahr. *C–C′* are two glass tubes containing the wicks, which were made in two different plaits (one composed of four wicks and the other of six wicks). *D–D′* are graduated cups, which measured the cubic centimetres of oil per hour. *T* is a thermometer for checking the temperature of the oil in the box.

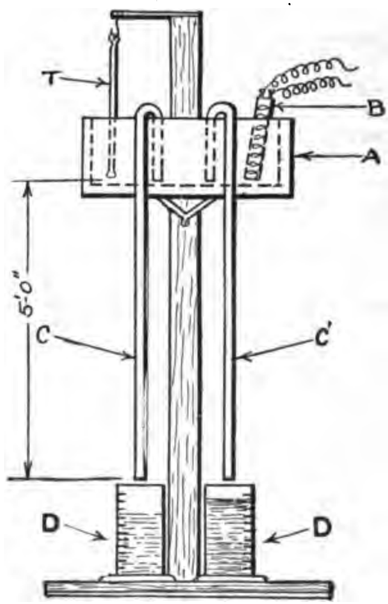

FIG. 2. SEC. 10*aa*.—Apparatus designed to compare the rates of feed for wick-feeds supplied with compounded and uncompounded oils.

The tubes were made 5 feet long, from the top of the siphon to the bottom of the tube. (This is the average length of feed for the medium-sized boat.)

The results of several tests showed that for different numbers of wicks, as described, and a wide range of room temperatures, the amounts of the compounded oil and uncompounded oils fed were about the same, when the working temperature in the box was the same, and the same number of wicks was used.

The compounded oil consisted of 20 per cent. rape oil, 80 per cent. petroleum oil. Say. Vis. at 100° F. = 690° Saybolt.

The mineral engine oil had a viscosity of 465° Saybolt at 100.

NAVAL OILING SYSTEMS

NAVAL OILING SYSTEMS.—The latest types of torpedo-boat destroyers in the United States Navy are equipped with turbines arranged on two shafts. The cruising turbine shaft is geared to the forward end of the starboard shaft. The reduction ratio is about 7 to 1. The L. P. ahead and astern turbines are on the starboard shaft.

A Metten Clutch, which is designed to uncouple the reduction gear from the main turbine shaft, is placed between the reduction gear and the L. P. turbine. This clutch uncouples the reduction gear from the main shaft when the revolutions exceed a speed corresponding to about 22 knots. The H. P. ahead and astern turbines are on the port shaft.

The lubricating system of the ship just described consists of two oil pumps and one oil cooler of 210 square feet of cooling surface. Forced-feed lubrication is supplied to all main bearings, thrust bearings, reduction gear, and main circulating engine bearings. The main circulating pump has a separate oil pump driven from an eccentric strap. A small plunger pump supplies oil pressure to the Metten clutch and is driven by a reduction gear. One oil drain tank of 205 gallons capacity, a main storage tank of 550 gallons capacity, and two oil-settling tanks of 200 gallons are included in the system. Each bearing is fitted with thermometers, observation boxes, and regulating cocks.

The latest battleships are equipped with a lubricating system as follows: All working parts of the main engines, except the valve stem guides and valve links, are fitted with forced-feed lubrication. There are two complete and distinct systems, the starboard and the port. There is a connection between the two, for emergency. Each system consists of three pumps, two 500-gallon tanks for storage, one 500-gallon oil supply tank, and one 500-gallon oil-settling tank. The entire engine is enclosed by a galvanized sheet-steel casing to prevent splashing and waste of oil.

The operation of the system outlined above is as follows: One pump draws the oil from the supply tank and discharges to the main engine. thrust bearing, and main circulating pump engines that are on its side of the ship. Holes in the caps of the main bearings permit the entry of the oil to the circuit. There is an annular groove in the centre of each main bearing, which aids the proper distribution of the oil, part of which lubricates the bearing, and the excess passes out through a radial hole in each journal, in the wake of the groove to the crank-shaft holes, which are axial. From the axial holes the oil is forced through radial holes to the eccentric straps and crank-pin centre holes, and out through radial holes to the outer surfaces of the crank-pins. The excess of oil from the crank-pins passes up through the connecting rods, to the cross-head bearings and guides.

The escaping oil is drained to the crank-pit, collected in the drain-well, and pumped by the second pump through the filters to the main supply tank. The third pump is used for the auxiliaries. The system is operated at about 30 pounds pressure.

The valve links and valve stem guides are lubricated by combination sight- and wick-feed oil distributing boxes located on the main cylinders. The axial holes in the crank-pins of a ship having two main engines, which developed 24,800 H. P. at 125 revolutions per minute, are about

8 inches in diameter, and the pins themselves are about 19 1/2 inches in diameter and 21 inches long.

FORCED LUBRICATION, MARINE.—Fig. 4, Sec. 10aa, shows an outline drawing of the forced lubrication system on the U. S. S. *Wyoming*, as given in an article on "Forced Lubrication," by Lieutenant Commander A. T. Church, U. S. N., in the *Journal of the American Society of Naval Engineers*, August, 1917, p. 443, and in this article the following data were given as to the pressures used in the systems of various vessels of the U. S. Navy:

U. S. S. *Texas* (reciprocating engines): On the main engines the pressure usually carried at the pump is 20 pounds. Running at full speed this pressure is increased to 30 pounds.

U. S. S. *New York* (reciprocating engines): Pressures carried on the discharge side of strainers are from 20 to 30 pounds gauge.

U. S. S. *New Hampshire* (reciprocating engines): Between 10 and 20 pounds by the oil-pressure gauges on the various parts of the system.

U. S. S. *Delaware* (reciprocating engines): 15 to 35 pounds, depending upon the viscosity of the oil and the speed of the engines.

U. S. S. *Michigan* (reciprocating engines): An oil pressure of 10 to 25 pounds is carried, depending upon the speed of the engines.

U. S. S. *Florida* (Parsons' turbines): The pressure carried on the Parsons' four-shaft turbines are 50 pounds at the pump and 10 to 12 pounds on the farthest bearings.

U. S. S. *Arkansas* (Parsons' turbines): For cruising speeds, the starboard oil pump discharge pressure is 50 pounds gauge, the port 65 pounds, and this gives an average oil pressure at the bearing of about 5 pounds gauge on each engine.

U. S. S. *Utah* (Parsons' turbines): Pressure at the pump before passing through the cooler, 25 pounds; pressure in system after leaving cooler, 12 pounds; average pressure on bearings, 9 pounds.

U. S. S. *Wyoming* (Parsons' turbines): Pressure carried at the farthest bearings for 10 knots and above, 10 pounds; for below 10 knots, 9 pounds.

Fig. 5, Sec. 10aa, shows the aft end view of a glared turbin unit. It will be noted that the oil is applied through pressure regulating valves to each half of the jack shaft pinion. The bearing taking the propeller thrust is shown at the left.

LUBRICATING CONDITIONS ON A BATTLESHIP.—The following data were found to be the average for the new types of dreadnoughts:

Average engine-room temperature	92° to 95° Fahr.
Average injection water temperature to bearings (water-cooled)	79° to 84° F.
Average R. P. M.	83.5 for 14 knots
	34 for 6.2 knots

LEAKY SYSTEMS.—There are two classes of leaks—oil and water. Oil leaks are detected as follows, according to Lieutenant Commander A. T. Church, U. S. N.:

(*a*) A decrease in quantity of oil in drain tank indicates a leak in the system.

(*b*) Oil leaks in the coolers are detected by tapping a small pipe into the highest point of the salt-water side of the oil cooler. This pipe serves

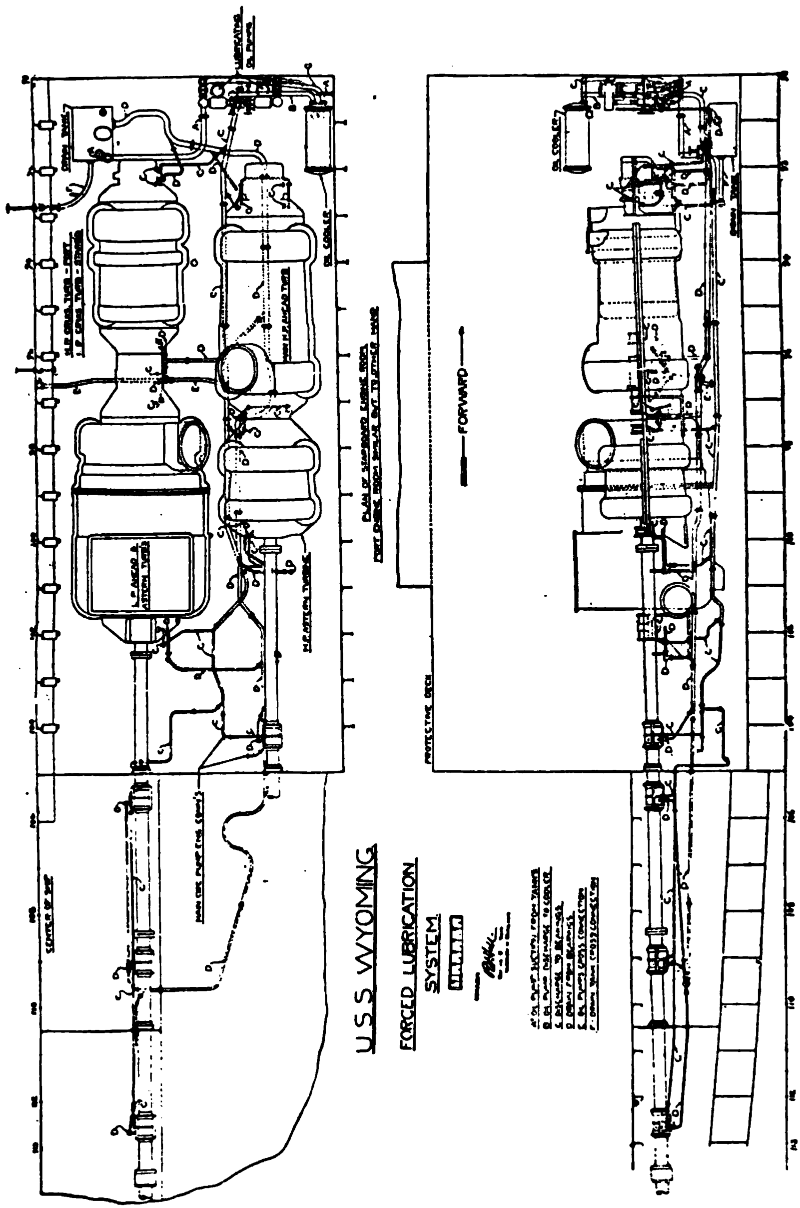

Fig. 4. Sec. 10aa.—U. S. S. *Wyoming* forced lubrication system. (Courtesy Journal of the American Society of Naval Engineers.)

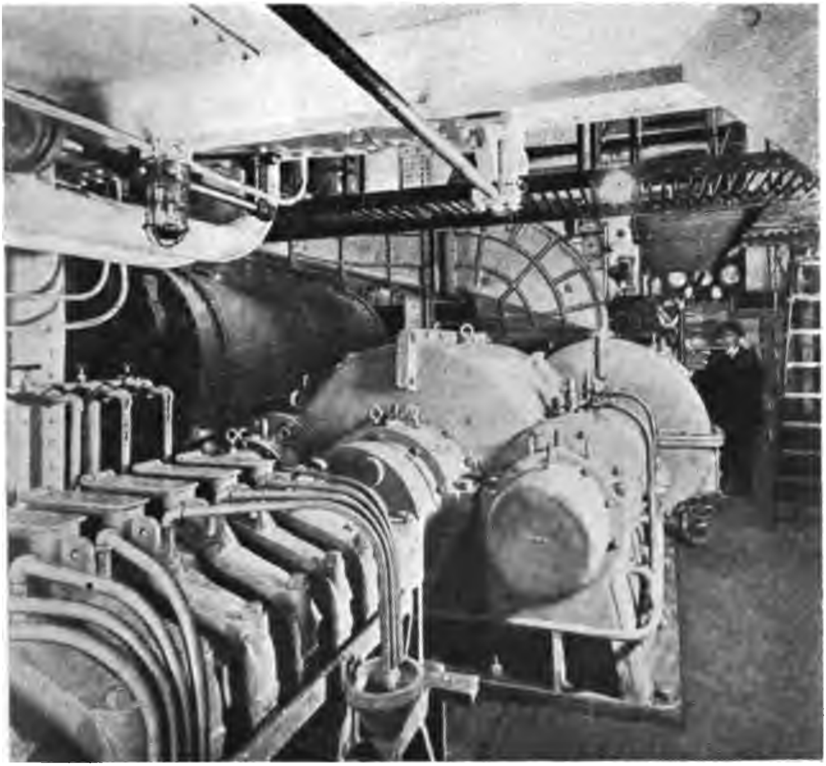

FIG. 5. SEC. 10aa.—Aft end view of geared turbine marine unit.

to allow escape for the air, and will indicate oil if any oil is leaking past the ferrules of the cooler.

(*c*) Increase in speed of the oil pump, and a sudden drop in the pressure registered by the oil gauges, indicates that a feeder valve in some part of the system is opened too far and flooding is occurring. If the pressure gradually drops and the supply pump speeds up accordingly, the trouble is usually due to wear of grasshopper joints to cross-head bearings, or in main bearings, and should be remedied in port.

Lieutenant Commander Church suggests, that a ready means of remedying leaks in engine casings is by filling cracks with litharge and glycerin.

TANK CLEANING.—The tanks of forced-feed circulating systems must be regularly inspected, at least monthly. The practice in the Navy is to pump the oil into a treating tank, and to treat it by raising the temperature high enough to precipitate the water and sediment. The tanks are swabbed and then boiled out. The oil can then be returned to the system.

OIL COOLERS.—An important part of the lubricating system for all ships fitted with forced-feed lubrication is the oil cooler. A typical installation found on a torpedo-boat destroyer may be described as follows:

Capacity per hour	3000 gallons
Film space	3/16 inch
Cooling surface	131.76 sq. ft.
Length over all	7 feet 7 3/4 inches
Diameter circulating water inlet and outlet	3 inches
Diameter oil inlet and outlet	2 1/2 inches

The circulating water for the oil cooler was supplied from the main pump, and the cooler had a capacity sufficient to cool all the oil in the system from 130° Fahr. to 100° Fahr. when the water was supplied at 60° Fahr.

MARINE MILEAGE CONTRACTS

KNOTS AND NAUTICAL MILES.—The "nautical mile," which is used for sea measurements, is equal to 6080 feet, and is thus about 15 per cent. longer than a statute mile.

A "knot" is not a distance, but a rate of speed, which is one nautical mile per hour. The term "knots per hour" is incorrect and should never be used.

MARINE LUBRICATING REPORTS.—The large steamship companies require reports from the engineers of their various ships to be rendered after each round trip, showing the oil on hand, and the mileage made. The mileage reported is supposed to be corrected to correspond with any alteration in the ship's regular course.

If the steamship company has a contract with an oil company to lubricate its ships at a fixed rate per mile, a duplicate report is sent to the oil company for its records. The large ship-owning companies keep tabulated records of their cost of lubrication per mile for their various ships. A specimen report now used by a well-known steamship company, having a "mileage contract" with an oil company, is shown below. This report is made in triplicate. The first copy is white, the second is pink, and the third is yellow. One copy is retained by the ship's engineer, one is sent to the marine superintendent's office, and one copy is sent to the oil company.

LUBRICATING MILEAGE REPORT

Steamship.................................Voyage Number............

Date sailed.......................... Date returned.........

	Cylinder oil	Marine-engine oil	Dynamo oil turbine oil	Crank-case oil
Gallons oil on hand from voyage number (............).......				
Gallons oil received date (............)..........				
Total gallons on hand sailing....				
Gallons oil used voyage number (............).............				
Gallons oil carried ahead........				
Total miles run on voyage number (............).............				
Gallons of oil used per mile......				

Signed, Chief Engineer......................

NOTES ON AMOUNTS OF OILS USED BY DIFFERENT CLASSES OF VESSELS.—The average river tug, with 150 to 200 H. P. engines, will use about five gallons of cylinder oil per month and about fifteen gallons of engine oil.

A moderately new steamer in the coasting trade, having a three-cylinder, triple-expansion engine (25 x 4 1/2 x 68 x 42), 2820 I. H. P., steam at 170 pounds pressure, and a net tonnage of 1994 tons, gave the following results in gallons of oil used per mile (*nautical*):

Gallonage Per Mile

Number of miles run	2850.
* Mean gallonage marine engine oil used per mile	0.0655
Mean gallonage cylinder oil per mile	0 00314
Mean gallonage dynamo oil per mile	0.00346

The same ship was lubricated with a straight mineral oil and gave the following results:

Number of miles run	8550.
† Mean gallonage mineral oil used for engines and blowers	0.069
Mean gallonage cylinder oil per mile	0.0036
Mean gallonage dynamo oil per mile	0.0036

* NOTE. The above figures are merely given as an indication of the relative amounts of oil used in this class of service and are subject to considerable variation in practice. The marine engine oil used had a viscosity at 100° Fahr. of 580° Saybolt, and was a rape compounded oil, having 20 per cent. compound. The above ship was equipped with two blower engines above the boilers, which used an excessive amount of oil.

† NOTE. The marine engine oil was a straight mineral, paraffin oil of 375° Vis. at 100° Fahr., and cost, at the time the test was run, 10 cents per gallon less than the rape compounded oil in the previous test. The saving is apparent. A great saving, in the average cost of oil for any ship, can be made by using straight mineral engine oil instead of a compounded oil, provided the engineer of the ship can be made to coöperate with the oil company and forget his prejudice against the uncompounded oil. There is absolutely no reason for the continued use of rape oil in marine engine oils, and the high cost of this oil should stimulate investigations and tests looking towards its discontinuance. It is particularly unsatisfactory for use with wick feeds, and yet ship engineers continue to go through the disagreeable operation of removing gummed wicking from the feeds and cleaning the tubes, rather than depart from their old customs and carefully try out the mineral oil.

TYPICAL MILEAGE REPORTS, SHOWING COMPARATIVE MILEAGE PER GALLON OF OIL OBTAINED IN THE MERCHANT AND OTHER MARINE SERVICE

Ship	Description of equipment
"A".....	Triple-expansion, 28 x 45 x 72 x 54. 381 N. H. P. Working boiler pressure, 185 pounds per square inch. 3500 I. H. P. 1987 net tonnage.
"B".....	Triple-expansion, 28 x 38 x 74 x 54. 402 N. H. P. Boiler working pressure, 160 pounds per square inch.
"C".....	Two-cylinder engine, 38 x 74 x 54. Gauge pressure, 110 pounds per square inch.
"D"....	Three-cylinder, triple-expansion, 25 x 41½ x 68 x 42. 300 N. H. P. 2820 I. H. P. Working steam pressure, 170 pounds per square inch. 1994 net tonnage.

Running Test on Above Ships

Ship	Service	Mean mileage	Gallons engine oil per mile	Gallons cylinder oil per mile	Gallons dynamo oil per mile
"B".....	North Atlantic	1632	.04232	.006437	.00491
"A".....	North Atlantic	1243	.04680	.005450	.00458
"C".....	North Atlantic	953	.03887	.002440	.00211
"D"....	South Atlantic	950	.06550	.003140	.00346

Note.—The oil used for the main engines was a rape-compounded engine oil, having 20 per cent. rape and a viscosity of 575 Say. at 100° Fahr.

The cylinder oil was used for swabbing the rods and was a straight mineral oil of 145 Vis. at 100° Fahr.

The dynamo oil was classed as a crank-case oil for the high-speed, direct-connected lighting engine.

AVERAGE MILEAGE-LUBRICATING RESULTS.—The following results are the average obtained on tests made on 21 coastwise ships of various tonnage, ranging from 2090 to 3100 gross tonnage:

Average gross tonnage of ships	2,744
Average indicated horse-power	2,062
Average total mileage	23,412 per ship
Average length	266 feet
Average depth	19.1 feet
Average beam	40.9 feet
Average gallons marine engine oil (per average total mileage)	759.9
Average gallons marine engine oil (per average mile)	0.0324
Average gallons rod-swabbing oil (per average total mileage)	69.7
Average gallons rod-swabbing oil (per average mile)	0.00297

Engine oil used tested:

345 Vis. Say. at 100° F.
410 flash.
45 pour.
3 per cent. No. 1 lard oil.
17 per cent. Cylinder stock (110 Vis. at 212° F.).
80 per cent. red paraffin (260 Vis. at 100° F.).

Rod-swabbing oil used—Straight mineral (600 steam refined stock):

150 Vis. Say. at 212° F.
Dark.

CONTRACT FORM FOR MARINE MILEAGE LUBRICATING CONTRACT.—The following contract was used in connection with the lubricating contract of a large steamship line, whose ships were lubricated on the basis of a fixed rate per mile.

Some contracts are further based on a rebate system, which gives certain returns to the steamship company, providing the gallonage consumed is kept below a certain amount, and the rebates are figured on a sliding downward scale.

(SPECIMEN) MARINE MILEAGE LUBRICATING CONTRACT

This Contract, entered into this........day of........1919, between the Oil Refining Company, hereinafter referred to as the Oil Company, and the A. B. C. Steamship Company, hereinafter referred to as the Transportation Company.

Whereas, It is agreed that the Oil Company will supply the Transportation Company with such quantities of marine engine, cylinder, crankcase, and dynamo oils, coming under " Engine-room Department," as may be necessary for the lubrication of its ships, the quality of these oils to be the best and equal in quality to the oils listed below, which oils have been tested out on the S. S. *Xantiope*, and proven satisfactory, with the understanding, however, that under their use efficient lubrication is hereby guaranteed. If the oils furnished do not prove equal in quality to the oils listed below, the Transportation Company reserves the right to cancel this contract.

The oils to be supplied are the following:

(*a*) Beta Marine Engine Oil .... 60.00 cents per gallon
(*b*) Beta S. R. Cylinder Oil .... 30.00 cents per gallon
(*c*) Beta Crank-case Oil .... 28.00 cents per gallon
(*d*) Beta Engine Oil (Dynamo) ..... 122.00 cents per gallon

The above list of oils supplied for the general lubrication of the ships operated by the Transportation Company. For the S. S. *Jacob* the following special oils will be furnished:

(*a*) Beta N Cylinder Oil .... 27.00 cents per gallon
(*b*) Beta Marine Engine Oil .... 44.00 cents per gallon

These oils are to be billed at the mileage rate indicated, and this contract is to cover deliveries to the steamships sailing from New York and Norfolk.

The Oil Company agrees to lubricate all ships owned and operated by the Transportation Company on the basis of 2 cents per mile, for a period of one year from January 1, 1920, with the understanding that this contract will be continued, at the option of the Oil Company, for another period of six months or one year, to be determined at the time, unless written notice of discontinuance is given by either party one month previous to the expiration of this contract.

This contract does not include the lubrication of tugs owned by the Transportation Company, and the Transportation Company agrees to purchase lubricating oils used thereon from the Oil Company on the gallonage basis, at the prices quoted above, delivered at the Transportation Company's Piers, New York and Norfolk.

The Transportation Company agrees to furnish the Oil Company at the end of each month a complete statement of the mileage made by each of its ships, the amount of oils used thereon, and the amount remaining on hand, whereupon the Oil Company will render billing for the mileage covered at the price quoted herein, payment to be made on or before the fifteenth of the month succeeding that in which the oils were used.

The Transportation Company agrees to exert its best efforts to have its employees use the lubricating oils supplied by the Oil Company as economically as possible and to avoid loss and waste of same, and should it be found necessary, the Oil Company will furnish, at its expense, inspectors to supervise the proper use and application of oils, upon plans approved by the proper officials of the Transportation Company, agreeing that their supervision shall be without friction with any of the employees of the Transportation Company and without any interference whatever with the Transportation Company's ships.

Due to the short lay in port of some of the Transportation Company's ships, it is necessary that prompt delivery be made, and the Oil Company agrees to use its best efforts to facilitate such delivery, the oils to be delivered in barrels or half-barrels, at the option of the Transportation Company.

All barrels or half-barrels in which oils have been delivered to the Transportation Company by the Oil Company are to remain the property of the Oil Company, the Transportation Company agreeing to take care of the barrels or half-barrels and to be responsible for same until they are delivered to the Oil Company.

All barrels or half-barrels delivered by the Oil Company to the New York piers of the Transportation Company will be returned to those piers for collection by the Oil Company, and all barrels or half-barrels delivered to the Norfolk piers of the Transportation Company will be returned to those piers for collection by the Oil Company.

It is understood and agreed that the Transportation Company is to return all barrels and half-barrels in good condition, subject to the inspection of the Oil Company, inspection and dockage for breaks as follows:

3-inch bung holes, dished and buckled heads, broken heads..	10 cents each
Missing heads	20 cents each
Broken staves	10 cents each
Missing hoops	5 cents each

The Oil Company shall not be held responsible for losses resulting from delays in filling orders by reason of strikes, fires, differences with workmen, or any cause beyond its control.

THE OIL REFINING COMPANY.
BY H. A. JONES.

ACCEPTED:

THE A. B. C. STEAMSHIP COMPANY.
BY HENRY SMITH, General Manager.

U. S. GOVERNMENT SPECIFICATIONS, MARINE ENGINE OIL.—(Report of Committee on Standardization of Petroleum Specifications, April, 1920):

1. This specification covers the grade of oil used by the United States Government and its agencies for the lubrication of reciprocating steam engines in marine service where a compounded engine oil is required.

This oil must not be used in circulating or forced-feed systems.

PROPERTIES AND TESTS

2. The oil shall be a compounded oil made from refined petroleum oil and 10 per cent. to 20 per cent. of blown refined rape-seed oil or blown refined peanut oil; so compounded that it will not separate or break down in any way either before or while in service.

3. Viscosity: The viscosity shall be 65 to 76 seconds at 210° F. Not over 700 seconds at 100° F.

4. Pour Test: The pour test shall not be above 32° F.

5. Acidity: The oil shall not contain more than 1.50 per cent. of acid calculated as oleic acid (equivalent to 3.0 mg. KOH per gram of oil).

6. Corrosion: A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

7. Emulsifying Properties: The oil shall remain completely emulsified for an hour from an emulsion with: 1. Distilled water. 2. 1 per cent. salt solution.

8. Wick Feed: The oil shall show a flow at the end of 14 days of at least 30 per cent. of its flow at the end of the first 24-hour period.

9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

WAVE QUELLERS

STORM OIL.—Capillary waves, whose size and height depend upon the surface tension of the water, are forerunners and upbuilders of the regular sea waves. As long as the wave mechanism is not disordered; that is, as long as the particles of water are allowed to move in their unrestricted orbits or paths, there is no breaking of the waves. When this condition occurs, vessels can ride from the hollows to the crests of the waves without shocks or the shipping of water.

The function of a wave queller is to be capable of quickly spreading over the surface of the water, and to make the surface tension less than the surface tension of water by as great a margin as possible. It must form a continuous surface film, whose particles are distinct from the particles of water, and, therefore, do not share their orbital motion.

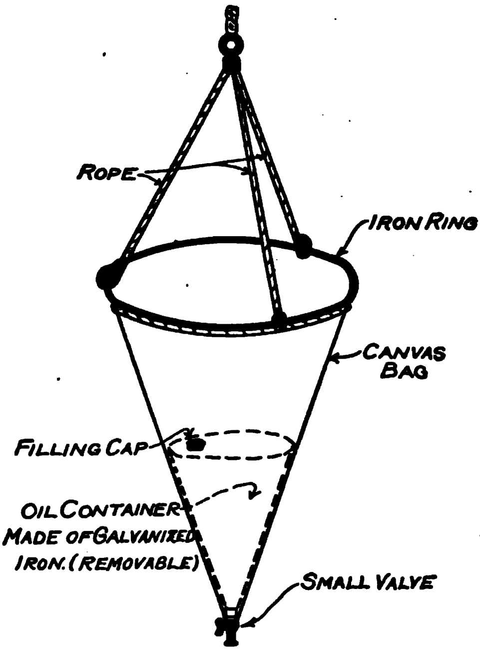

Fig. 6. Sec. 10*aa*.—Sea drag.

When a film of oil is spread over the surface of the water, the heaping-up action, as it may be called, which, in the case of the water film, results in the formation of ripples, cannot take place. This condition toward heaping up is changed to one in which the tendency is to move the entire surface film along at a uniform rate.

Theoretically, soapy water is the best agent for use as a wave queller. It has superior spreading power and affords great reduction of the surface tension. In practice, however, oil appears to have the advantage over soapy water, and has the added feature of not mixing with it.* This property is of value, in that when spread over the surface of water, the oil maintains itself as a distinct layer, the particles of which do not take up the orbital motion that the particles of water have in sea waves.

The quantities of oil used by a large ship when riding out a gale do not, as a rule, exceed five or six gallons.

One of the most successful storm oils is fish oil. Usually the so-called "Dark Fish Oil" grade is used for the purpose.

Passenger-carrying vessels usually carry a supply of storm oil during the stormy months of the year.

The old method for applying storm oil seems to be as follows: Small

* See index for fatty acids and interfacial tension between oil and water.

canvas bags, which have been punctured with a sail needle, are hung over the side of the ship, so that they trail in the water. These bags hold about two gallons of the oil apiece.

When "running before the wind," the bags are hung from the bow and towed in the water. When "lying to," the bags are suspended in the water, from the "weather bow."

On some ships the oil is ejected into the water by forcing it out through the toilets.

Animal and vegetable oils and engine-oil drippings are often used for this purpose. Kerosene is said to be of little use. When a petroleum oil is to be used, a light, free-flowing oil, such as a 28° paraffin oil, is recommended.

SEA DRAG.—Fig. 6, Sec. 10aa, shows a typical "sea drag," which is provided as part of the equipment of small boats. The drag consists of a cone-shaped canvas bag, which is attached to an iron ring at the top.

A conical-shaped, galvanized iron container is fitted in the lower part of the canvas bag, as shown in the cut. This container holds about a gallon of storm oil, and is provided with a small valve cock at the bottom, through which the oil is allowed to seep into the water when the drag is drawn by the ropes as shown.

This type of drag requires a light, free-flowing storm oil. If an oil of heavy body is used, it will form in drops and will not spread over the surface of the water as is desired. As the size of the valve is about 1/4 inch or smaller, it can be appreciated, that if the oil used is too heavy in body there will be difficulty in getting it to flow through the valve into the cold water.

A light paraffin oil of about 150 Vis. at 100° Fahr. will give good results.

GENERAL RULES OF THE SUPERVISING INSPECTORS.—The Supervising Inspectors have made the following rules for boats on the Great Lakes and inland waters:

All boats of 3000 to 5000 tons must be equipped with two tanks of 20 gallons capacity for carrying storm oil. These tanks must be fitted with suitable hose connections for getting the oil overboard.

Boats of 5000 tons and over must have two 25-gallon tanks.

Boats of 200 to 1000 tons must have two 10-gallon tanks.

The tanks should both be located forward.

SPECIAL MARINE PRODUCTS

"SLUSHING OIL."—This oil is used for rough work on winches, etc. Summer or winter black oil is recommended for this purpose.

SIGNAL OIL.—Mineral seal, or 300° oil, is usually used for the running lights of ships.

Signal oils made with 300° oil and 20 per cent. to 30 per cent. of "burning lard," or 300° oil and 20 per cent. of sperm oil, are also used.

BUNKER LIGHTS.—Colza burning oil, which usually consists of about 50 per cent. to 50 per cent. of mineral oil, compounded with Colza oil, or cottonseed oil, is burnt in the small lamps used by the stokers. These lamps are usually made with two burners. The oil used in these lamps must have a high fire test and must burn without smoke. Special lamps are made that will melt and burn a low melting-point paraffin wax. Sometimes cottonseed oil is used to compound oil for bunker lights, instead of Colza oil.

LOCATION ABOARD SHIP.—Looking towards the bow, or head, of a vessel, the left hand is on the "port side" and the right hand is on the "starboard side." To "port the helm" carries the vessel's head to the starboard, and to "starboard the helm" points the vessel's head towards the port.

FUNNEL MARKS OF ATLANTIC SHIP LINES.—The American Line has a black-white band and white top; the French, red, with black top; the Cunard, red, with black rings and black top; the Hamburg-American Express Service, buff, regular black-white band,. black top; the White Star , buff, with black top.

STROKE OF THE PISTON.—According to Seaton & Roundthwait's Pocketbook of Marine Engineering: "For ordinary cargo steamers, the length of the strokes of the piston is about .65 times the diameter of the low-pressure cylinder.

SLIP OF THE SCREW.—Often in estimating marine lubricating contracts it is necessary to determine certain facts regarding the revolutions, etc., from the mileage made. It is, therefore, thought advisable to give the following information, which was obtained from standard authorities: The speed of a ship through the water is less than the multiple of the revolutions and the acting pitch. The difference between them is the "apparent pitch." In the mercantile marine, with reciprocating engines, an apparent slip of 10 per cent, and with turbine engines of 15 per cent., is considered normal.

Some results of actual measurement of slip are taken from Seaton & Roundthwait's Pocket Book:

TABLE OF VARIOUS SLIPS

Type of Boat	Speed Knots	R.P.M.	Pitch	Slip Per Cent.
Single-screw passenger	16.16	64.5	29′	12.6
Single-screw cargo	11.40	70.0	19¼′	14.3
Twin-screw tug	11.1	141.0	10¾′	25.7
Twin-screw express str	22.8	77.2	32.8	8.89
Turbine express str	26.46	191.5	16.13	13.2
Battleship	18.5	110.0	19¾	13.3
Naval cruiser, turbines	25.95	378.4	8.7	20.1

SECTION 10bb

MINING OPERATIONS

GENERAL.—The strongly corrosive waters to be pumped in mining operations have a particularly bad effect upon the plungers and piston valves of the pumps. These conditions must be reduced as much as possible by suitable lubrication, so that exposed surfaces will be covered by a film of lubricant.

Mining operations are examples of methods of lubrication producing great wastes of lubricants. This is due largely to the fact that the oiling operations are usually left in the hands of unskilled laborers, who waste more of the mine-car oil than is actually used for lubrication.

The largest item of expense in the lubrication of a mine is that due to the large amounts of mine-car oil used. The consumption of car oil at a mining operation naturally increases with the length of the "drifts" and the distances the cars must travel.

Mine cars are hauled by electric or compressed-air locomotives, and an inefficiently lubricated string of mine cars will greatly detract from the hauling capacity of the locomotives.

The friction losses in mine cars consist of bearing friction loss at the wheel journal or bore, and the rolling and flange friction, this last being a very small per cent. Mine car-wheel bearings are frequently subjected to large overloads.

CAR HAULING COSTS.—Experience has shown that a mule and driver costs about $550 per year.* If a train can be increased by improved mine car wheels and better lubrication from four to six cars, the cost of hauling per year, based upon the above figures, would be reduced from $137.50 per car to $91.66 per car. This is a direct evidence of the economy of scientific lubrication and improved mine equipment.

In the case of electric locomotives, the saving resulting from improved lubrication is easily measured by electrical instruments. The problem in a mine is to get the greatest number of tons over the line in the shortest time. Overloading of locomotives will result in slipping wheels, wearing of tires, strains on the machine, arcing and burning of the trolley and wire, overheating of the motor, and a general lowering of the voltage on the entire system. These can be avoided and an increased tonnage moved, provided the cars are scientifically lubricated and modern bearings installed.

The question of lubrication is not so important from the standpoint of wear on the equipment when the hauling is done by mules, as the speed is slow and the mules stop to rest frequently. In a case of electric haulage, where speeds of 15 or 20 miles per hour are maintained for several miles possibly, the question of lubrication is vital in the preservation of the equipment.

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* In 1913.

EFFECT OF LUBRICATION ON MINING COST.—In a mine coming under the writer's notice, it was found that during a period, when 500,000 tons of dead rock and coal was moved, $3000 per year was wasted, due to poor lubrication, waste, and time lost by the men fixing cars, that should not have needed repairs if they had been properly lubricated, and in looking for easy-running cars, when their own were in bad running condition, due to poor lubrication. In this mine a mechanic was put in charge of the lubrication of the mine, and effected a saving of $3500 the first year.

MINE-CAR LUBRICATION

One-quarter to one-half of the power generated at collieries, when they are operated, is used for hauling the cars.

Passenger and railway gondola cars give, on the average, from 1000 to 3000 miles per oiling. Mine cars are considered by the operators to be giving good results if they average 50 miles per oiling.

Fifty per cent. more oil is wasted than is used. Dirt, grit, and coal dust will cut the bearings, therefore all oiling holes should be kept covered.

There are several kinds of packing for use in mine-car lubrication, for wheels of the journal-box type, as follows: Discarded Manila roping, Mexican sea-grass, sponges, cotton waste, and woolen waste.

Woolen waste is the best, because it is of a springy nature, and, therefore, has a tendency to press up against the journal surfaces and bring the oil into contact with those surfaces. It will absorb the oil and gradually feed it to the journal, like a wick in a lamp.

Cotton waste becomes soggy and sags down in the "cellars." This waste also tends to fall away from the journal surfaces and glaze at the contact surfaces, so that it is impossible for the journal to receive oil in sufficient quantities.

Mexican sea-grass and old Manila rope do not absorb oil, but merely tend to hold it in the boxes. The grass is soon broken into small pieces and works up into the bearing, causing overheating.

The proper method for preparing wool waste for use in mine cars may be briefly described as follows:

(*a*) Tear the waste apart, into small pieces, about the size of an egg.

(*b*) Drop these pieces into a tank containing the car oil, which is kept at a temperature of about 80° Fahr.

(*c*) Drain the wool on a screen for six hours, after it has soaked in the oil for 24 hours. While the waste is draining, it should be occasionally stirred with a pole or hoe.

Sponges will not feed every drop of oil to the journal as wool waste will, due to many small holes in a sponge, which tend to hold the oil back.

It is a very good plan for the "oiler" to mark the date of each oiling on the journal boxes of the cars, so that a record may be kept of his work.

A typical mine-car oil would have the following general specifications: Black oil:

Viscosity, summer, 90–100 (Saybolt), at 212° Fahr. Cold test. 25–30° Fahr.

Viscosity, winter, 370–385 at 130° Fahr. Cold test, 5–15° Fahr.

For the old-style plain-bore car wheel, black oil is used. The oil is mostly lost by dripping and only a very small amount actually furnishes lubrication. The oil should have a cold test of about 5° for winter use.

A well-known semi-fluid grease, widely used in the mine cars of the coal districts of the United States had the following general tests:

Flash: 390° Fahr.
Fire: 435° Fahr.
Vis. at 212° F.: 70 Say.
Cold test: 35° Fahr.
Ash: 0.68 per cent.

(See index for semi-fluid grease characteristics.)

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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MINE-CAR WHEELS

There are numerous types of mine-car wheels on the market.

Some of them are of the old-style, plain-bearing type, from which most of the oil is wasted by dripping off, while others are of the more improved self-oiling types, which, to a more or less extent, give satisfactory results. Many mines have equipped their cars with roller bearings, which have met with some success. Many of the so-called self-oiling wheels are faulty, in that they do not provide sufficient means to prevent the oil from creeping out along the back of the hub and being lost.

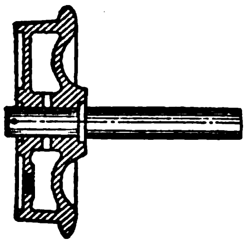

FIG. 1. SEC. 10*bb*.—Plain bore wheel.

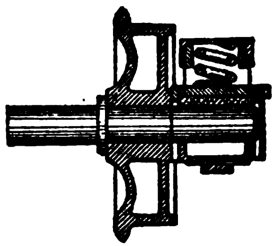

FIG. 2. SEC. 10*bb*.—Plain journal box wheel.

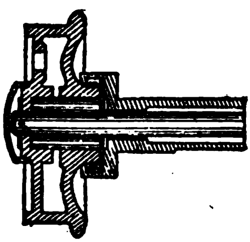

FIG. 3. SEC. 10*bb*.—Solid roller bearing wheel.

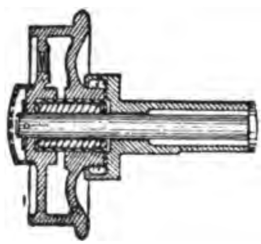

FIG. 4. SEC. 10*bb*.—Wheel with Hyatt roller bearing.

The four main types of mine-car wheels are shown in Fig. 1, Sec. 10bb, Fig. 2, Sec. 10bb, Fig. 3, Sec. 10bb, and Fig. 4, Sec. 10bb. These are conventional drawings.

VARIOUS CONSTRUCTION AND DESIGNS OF MINE-CAR WHEELS.—For the purpose of illustrating the lubricating requirements of some of the latest types of mine-car wheels in operation in the United States, the drawings are given as follows:

Fig. 5, Sec. 10bb, shows a sectional view through the wheel and axle of the Southern Wheel Company's Hollow Axle Truck. The main feature of this design is the method of feeding the lubricant from the reservoir into the wheel, by gravity, while the wheel is running. The axle is hollow

and of uniform diameter throughout. Three 1/2-inch holes are drilled radially in the axle directly over the gauge line. The annular groove in the wheel is two and one-half times wider than the diameter of the holes. Thus the groove in the wheel runs in register with the holes in the axle, and the inside of the axle is always in communication with the wheel bearing, permitting the lubricant to be fed by gravity from the axle into the wheel, while the wheel is running. The axle is full-floating and free to turn and move endwise, but does not revolve when the truck is running. A heavy summer black oil or a flowing grease lubricant is recommended

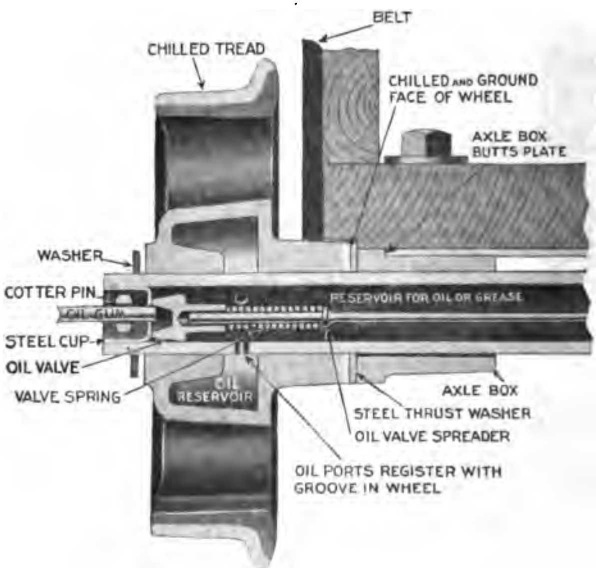

FIG. 5. SEC. 10*bb*.—Longitudinal section of hollow and wheel.

by the manufacturers as a lubricant, and in no case should a compression grease be used. The manufacturers advise that these wheels are operating successfully with black oil as a lubricant where the rope speed is 3000 feet per minute and an 18-inch wheel is used which makes 640 R. P. M.

Fig. 6, Sec. 10bb, shows a cross-section through the centre of the journal of this wheel, showing the position the oil or grease takes while the wheel is running. The arrows show the feeding action of the lubricant. The lubricant is fed out of the holes, into the groove of the revolving wheel.

Fig. 7, Sec. 10bb, shows a Hockensmith Wheel and Mine Car Co. wheel equipped with a Hyatt roller bearing. For the lubrication of this wheel, a semi-fluid lubricant* of three-quarter consistency is recommended.

* NOTE. In this and future references, the consistencies given refer to vaseline as (1), at normal temperatures.

Fig. 6. Sec. 10bb.—Illustrating principle of hollow axle and car wheel.

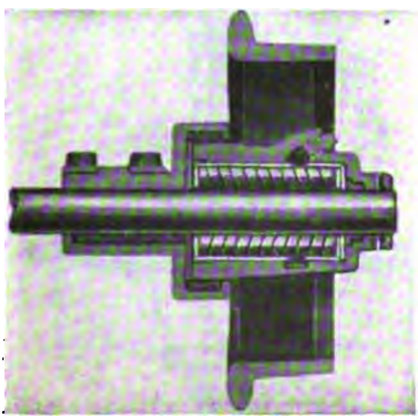

Fig. 7. Sec. 10bb.—Wheel equipped with Hyatt roller bearing.

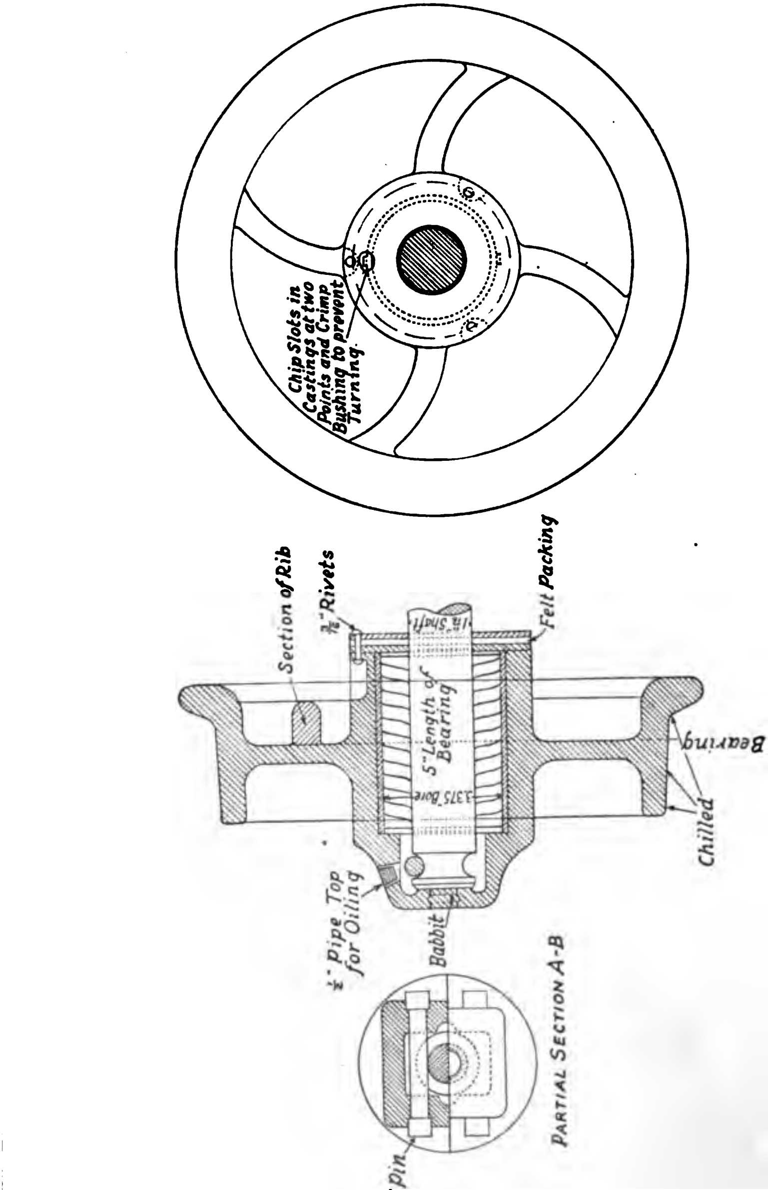

FIG. 8. SEC. 10bb.—Sectional and end view of Anaconda, 12" roller bearing, on car wheel.

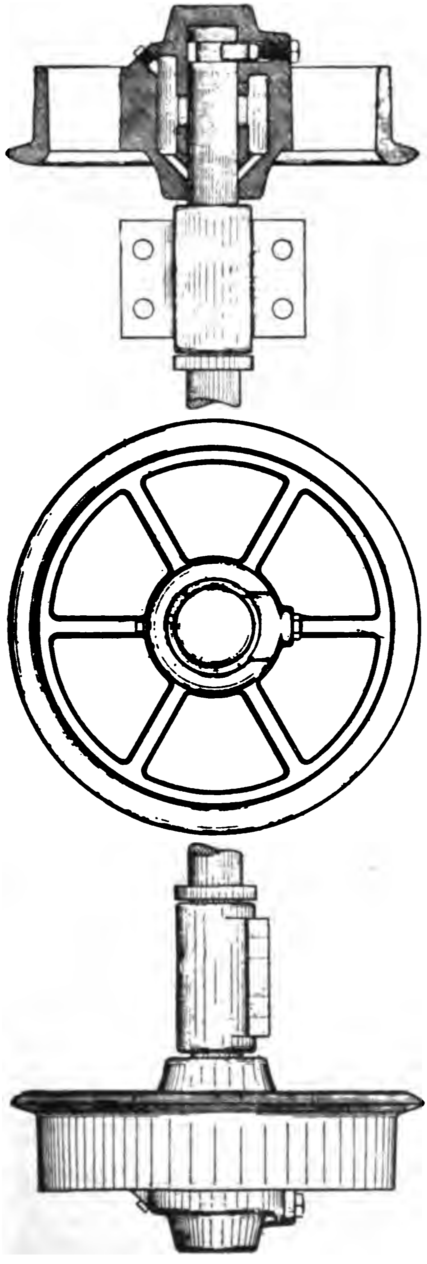

FIG. 9. SEC. 10bb.—D. P. Wheel with plain bearing.

Fig. 8, Sec. 10bb, shows a sectional and end view of an Anaconda, 12-inch roller-bearing ore-car wheel, made by the Anaconda Copper Mining Co., Foundry Department. For this type of wheel a semi-fluid grease of seven-eighths consistency is recommended for lubrication.

Fig. 9, Sec. 10bb, shows a D-P wheel, with plain bearing, made by the Kanawha Mine Car Co., of Charleston, W. Va. For this type of wheel a semi-fluid grease of seven-eighths consistency, or a cup grease, is recommended. Some mines prefer black oil.

Fig. 10, Sec. 10bb, shows a roller-bearing wheel made by the American Car and Foundry Co. For the lubrication of these wheels a semi-fluid grease of seven-eighths consistency is recommended.

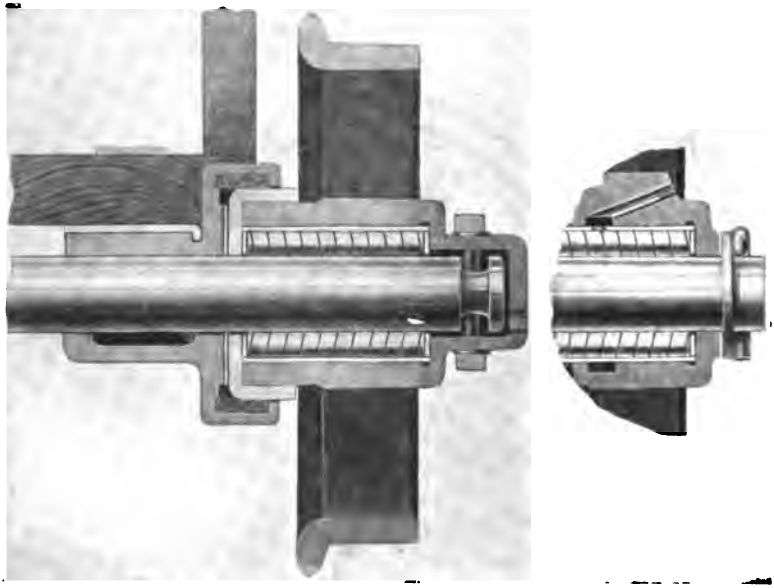

FIG. 10. SEC. 10bb.—A wheel made by the American Car & Foundry Co. equipped with the Hyatt Roller Bearing.

Fig. 11, Sec. 10bb, shows a sectional view of a "Whitney Wonder" roller-bearing wheel; also the roller bearing, wheel lining and wheel casting. For this wheel a medium cup grease is recommended. It is put into the wheel by means of a screw-pressure grease gun. Usually once in about four to six months is the average length of time between greasings. This wheel is made by the Sanford-Day Iron Works, Knoxville, Tenn.

Fig. 12, Sec. 10bb, shows a Phillips Star Wheel for mine cars, made by the Phillips Mine and Mill Supply Co., of Pittsburgh, Pa. Fig. 13. Sec. 10bb, shows a Phillips steel-cap wheel. Fig. 14, Sec. 10bb, shows a Phillips patent open-cap mine wheel, outside and sectional views, with

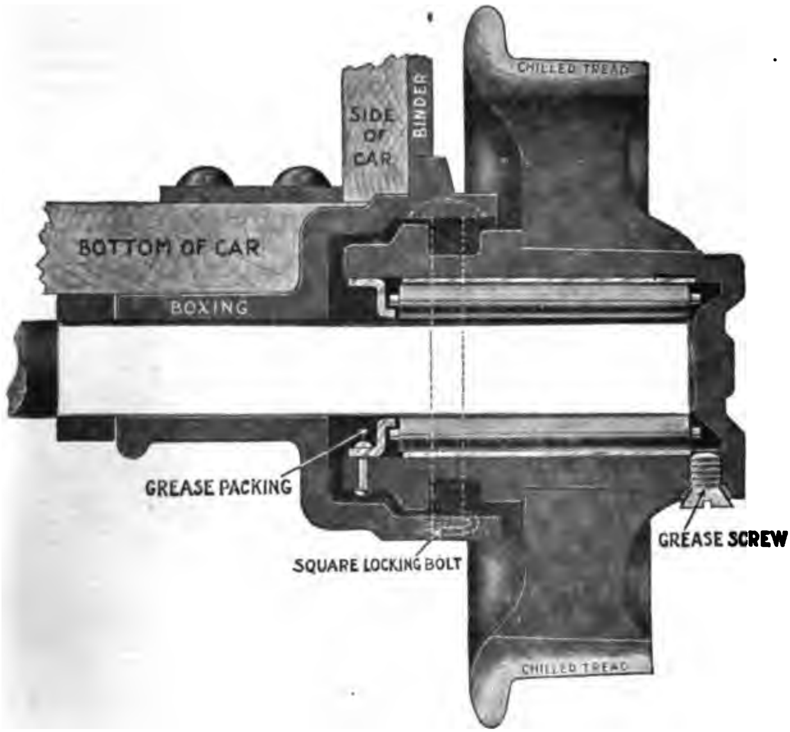

Fig. 11. Sec. 10bb.—Whitney mine car wheel.

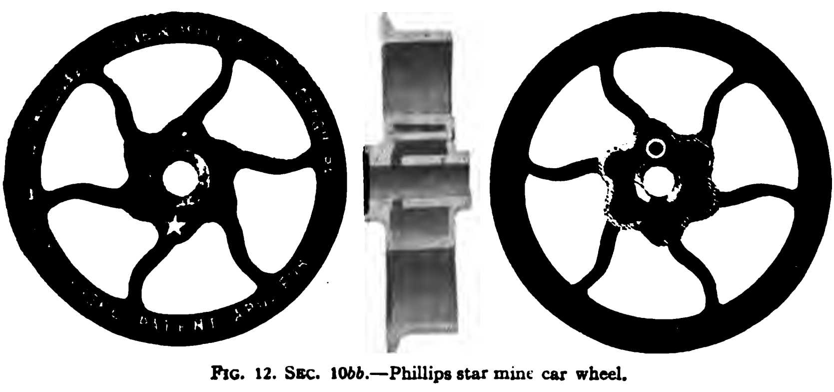

Fig. 12. Sec. 10bb.—Phillips star mine car wheel.

the axle. The lubricating arrangement of the open-cap wheel is similar to the arrangement used in the star wheel, except that the construction of the wheel is somewhat different, the bore at the front end of the wheel being 2 1/2 inches for a 2 1/4-inch axle. The open cap wheel is espe-

FIG. 13. SEC. 10*bb*.—Phillips steel cap mine-car wheel.

cially successful with grease lubrication, some of the wheels running six to eight months with one lubrication. For wheels in good condition use a semi-fluid lubricant of five-eighths consistency of vaseline, and for worn wheels use a lubricant the next consistency higher.

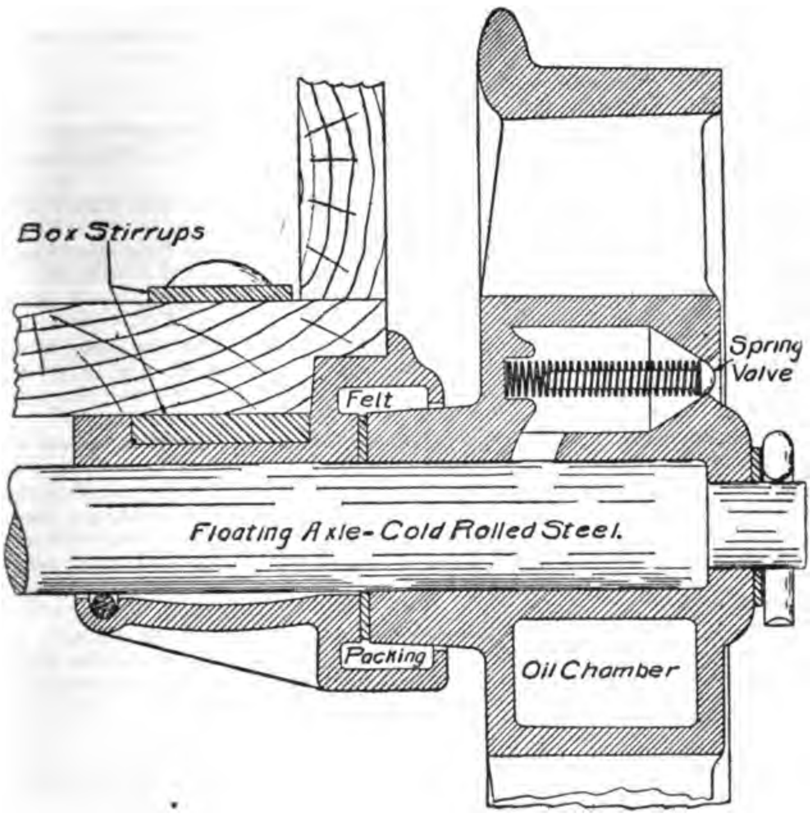

Fig. 14. Sec. 10*bb*.—Phillips patent open cap mine-car wheel.

COLLIERY AND OTHER EQUIPMENT LUBRICATION

The principal machinery in a mine colliery which must receive lubrication may be outlined as follows:

(COLLIERY)

(*a*) Steam cylinders.
(*b*) Pneumatic tools.
(*c*) Electric generators and motors.
(*d*) Air-compressor cylinders.
(*e*) Wire ropes and cables, etc.

(MINE)

(*a*) Mine cars.
(*b*) Mine pumps.
(*c*) Air cylinders.
(*d*) Wire cables and mine hoists, etc.

NOTES ON COAL MINING.—Every time a ton of anthracite coal and rock is hoisted from a mine, an average of eleven tons of water must be pumped from the mine.

Approximately 4000 tons per day is the output of the largest producer of anthracite in the world.

It takes about the same amount of power to pump fresh air into a mine as it does to hoist the coal out of it.

About the deepest coal mine is in the Wyoming region. It is about 2000 feet deep.

A "pick mine" is one in which the miners use hand work, picks being used to "undercut" and get out the coal. Mules are used to haul the cars. Little cylinder, engine, or compressor oil is required for this type of mine.

In some mines with long drifts, the car hauls may be as much as 15 miles per round trip.

When figuring a lubricating tonnage contract for a "wet mine," make allowance for the continual operation of the pumps, which are kept going night and day and use large amounts of lubricants. Also, in "wet mines," water collects in the low places and washes the journal oil from the "pit car" journals, greatly increasing the amounts of car oil used, due to the frequent reoiling.

In a well-run hard-coal mine, the following approximate amounts of oil were used to lubricate the pumps, cars, etc., for a period of one year, and the results are tabulated as an indication of the relative cost of lubrication of coal mines:

Cylinder oil	8,700 gallons
Engine oil	11,400 gallons
Car oil	31,650 gallons
Cup grease	35,000 pounds
Plunger pole grease	21,600 pounds
Other oil, such as ice machine, gas engine and compressor	1,200 gallons

Total coal tonnage mined during the above period, 3,900,000 tons.

WIRE ROPES IN MINES.—See index for lubrication of wire ropes. Wire ropes used in mines, for hoisting and haulage, are subjected to very severe usage. Great care must be exercised to keep these ropes in good condition, to prevent accidents. Shaft ropes are, as a rule, inspected

three times every 24 hours, and a written report of their condition is kept in a special book. The ropes are usually from 1 1/2 to 1 3/4 inches in diameter. There are usually six wire strands, laid around a Manila rope core, which, during manufacture, is pulled through a tank of soft grease (see index). There is a regulation as to the size of the pulley or sheave wheels, on which mine wire rope may be run. For this reason, the sheave wheels on a coal-shaft hoist are usually 12 feet in diameter, as smaller ones would cause greater strain and wear. It is true that wire rope is subjected to both internal and external wear, and there are really thousands of working surfaces.

Lubrication of the rope is not only necessary, due to wear, but also to protect the rope against attack from sulphur-charged mine water. A peculiar fact connected with this is, that ropes that are continuously wet are not subject to this attack, as is the case when the rope is alternately wet and dry. (See index for lubrication of wire ropes.)

Manila ropes are generally used in coal breakers. In some mines, waste black oil or grease is used. Excess lubricant, or more than the rope will absorb, will clog up the sheaves and throw off the rope .

MINING MACHINES.—The mining machines used in the soft coal fields are of two types, viz.: the cutting machine, which undercuts the coal vein, with knives or cutting blades, that are fastened to a chain, which travels around a triangular-shaped frame, and then the coal is blasted down. The second type is the hammer machine, which uses hammer blows, instead of a cutting action, to loosen the coal.

The hammer types of machines develop considerable heat, and the oil used on them must have a good flash test. Generally black, or as sometimes called, " pit car " oil, is used for the lubrication of the chains, and a machine oil of about 250 Vis. at 100° Fahr. (P. B.) or 350 Vis. at 100° Fahr. (A. B.) is used on the machines.

In some cases, the oil passages get badly clogged, due to carelessness, and in that case a lighter-bodied oil would probably be worked through better; but with proper attention to the machine, more economical results will be obtained with the heavier oil.

Due to waste, about one quart of machine oil is used every eight hours on the average cutter, but with the proper care the same results could be obtained with about a half-pint of the oil; exclusive of the chain, of course.

MINE PUMPS

PUMPS—ANTHRACITE MINES.—In the anthracite mines, pumps of 3,000,000 to 4,000,000 gallons capacity per day are quite common. Many types of pumps are used, among which are the electric motor driven pump, the triplex pump, and the centrifugal pump. The latter may be electric or steam turbine driven. Then there is the water hoist. This is operated by a hoisting engine, by which steel tanks of about 2500 gallons capacity, are hoisted up the shaft. When these tanks reach the surface, they are automatically dumped, either by tilting or by lifting a valve in the bottom. These hoists are expensive, but have the advantage that they are on the surface and are capable of bailing out a mine at times where a pump might be lost.

The Duplex plunger pump is one that is most commonly used, and is known about the mines as a " pole pump." The plunger extends beyond the pump barrel at each end for each stroke. In the larger pumps, the steam cylinders are compounded. Condenser pumps are used to take care of the exhaust steam. A low viscosity steam cylinder oil, carrying a good compound, is used in the steam cylinders. Valve rods and small moving parts are best lubricated with a cup grease. The most important feature of the lubrication of these pole pumps are the plungers.

PLUNGER-POLE GREASE.—In the past it was often the custom in the anthracite field to permit the pump man to make his own grease for use on the poles of the plunger pumps. There were consequently many different combinations in use. The most common was made of one or more of the following: Resin, pine tar, tallow, cylinder, and black oil. The material was put into a large kettle and fire-cooked, while being stirred for a certain length of time, and was a very crude method, which resulted in obtaining uneven batches, some of which were good and others bad. Too much tar in their mixture would result in a tendency to pull the packings and slow up the pumps.' A good grease will save steam and prolong the life of the pole and packing. A satisfactory plunger-pole grease must have no tendency to pull the packings, nor wash off with water. A graphited grease of good consistency is often used at the present time as a plunger-pole grease, while some use a petroleum residue, which is not as good as the former. The method of application may be either to throw the grease onto the pole with a paddle, or to apply it by hand all around the pole. Some operators warm the grease to the consistency of cylinder oil and apply it with a brush. The advantage of this method being that the grease may be applied in a thinner coat, so that it can work back to the packing. Another good reason for brush application is that the grease which collects on the end of the pole can be brushed around the pole and used over again. The temperature of the water pumped from the inside of the mine will run from as low as 40° Fahr. to as high as 110° Fahr. where the exhaust is run directly into the sump. In the boiler-house, the temperature may run as high as 210° Fahr. when pumped from an open heater. For slush pumps, which often pump as high as 60 per cent. slush, a soft graphite grease is recommended. For the various conditions as outlined above, three grades of plunger-pole grease (light, medium, and hard) are in use, to be selected according to the particular condition met with, all being graphited.

One of the important requirements of plunger-pole grease is that it must protect the plungers from attack by sulphur, with which the mine water is more or less heavily loaded. Should the sulphur attack the plungers, pitting will occur. If a graphited grease is used and pitting does occur, due to some unavoidable reason, the graphite will fill in the minute cavities.

There are several methods for applying the grease other than by means of the brush and paddle as previously described. One of the best methods is to provide two iron rings, spaced about one inch apart, and held in position by rivets. This ring is made a neat fit to the pump barrel and has about one-sixty-fourth-inch clearance around the plunger. If five rings of packing have been customarily used, one is left out. First, two rings of packing are put on, then the iron rings are put into place, followed by another two rings of packing; next a hole is bored through the top of the pump barrel, coming out between the spaced rings. Next a thread is tapped into this hole, and a grease cup fitted in it. This cup has a valve in the shank, so that it may be refilled while the pump is operating. This arrangement gives a very economical method of feeding the grease.

LAMP OILS

MINERS' OIL.—The following specification is used by a very large coal mining company for its purchases of miners' oil:

SPECIFICATIONS FOR MINERS' OIL

The material desired under this specification is an oil compounded from 65 per cent., by weight, of paraffin oil, and 35 per cent., by weight. of bleached fish oil. The oil is to be used in the miners' open lamps and must burn freely and steadily with the wick used in these lamps. When a shipment of oil is received, a sample shall be taken at random and forwarded to the office of the chemist. This sample shall be examined, and the entire shipment accepted or rejected on its merits. If rejected, the shipment will be returned at the shipper's expense. If the shipment is accepted, and it is found later that the oil in certain barrels is cloudy or contains suspended matter, these barrels will be returned to the shipper. notwithstanding the test report has shown the shipment to be ready for use. Shipments will not be accepted: First, if the oil is cloudy or contains suspended matter, or is not of uniform quality. Second, if the oil does not contain at least 30 per cent. fish oil of quality specified. Third. if the oil contains more than 2 per cent. free acid calculated as oleic acid. Fourth, if the flash-point of the oil is lower than 325° F. The flash-point of the oil will be determined by heating the oil in an open cup at a rate of not less than 15° F. per minute, and applying the test flame every 7° F. beginning at 304° F.

SUMMARY

65 per cent., by weight, paraffin oil.
35 per cent., by weight, bleached fish oil.
Must be clear and free from dirt.
Fish oil not less than 30 per cent.
Free acid not more than 2 per cent. (oleic).
Flash-point not below 325° F.

SECTION 10cc
NAVAL OILS

NAVAL LUBRICATING OILS.—Information concerning tests of lubricating oils at the Engineering Experiment Station. Issued by the Bureau of Steam Engineering, U. S. Navy. Subject to change or modification as found desirable.

1. All oils not known to be satisfactory are subject to test at the Engineering Experiment Station, Annapolis, Md., and to a further test in service on board ship when considered necessary before being considered acceptable by the Bureau of Steam Engineering.

2. Authorization of an oil test must be obtained from the Bureau of Steam Engineering, which Bureau directs the Engineering Experiment Station to conduct the test. The authorized tests are then given a number and are taken up in the regular order; persons interested being permitted to visit the Experiment Station and inspect the methods of testing employed.

3. All expenses of tests are borne by the concern requesting the same; the necessary quantities of oils being shipped to the Supply Officer, Naval Academy, Annapolis, Md., marked "*For Test at Engineering Experiment Station,*" and with all express or other charges prepaid. Before the test is started a check made payable to the *Superintendent, U. S. Naval Academy.* must be mailed to that official at Annapolis, Md., to cover the costs of tests; any unexpended balance being returned to the exhibitor.

4. All tests are made with the strict understanding that they are for the information of the Government only, and that results of tests are not to be used as an advertisement.

5. The cost of tests varies with the labor involved and the number of oils tested, the expense being reduced where an oil proves unacceptable in the early stages of the test.

6. In general, a deposit of $30 is required for a test of one oil and $200 for six or eight oils, the amounts of each oil required by the Experiment Station being from five to twenty gallons.

7. The complete test of an oil consists of three parts. namely, chemical, physical, and practical tests.

8. To successfully pass the *chemical* tests *all* oils should be neutral in reaction, and should not show the presence of moisture, matter insoluble in petroleum ether (hard asphalt), matter insoluble in ether alcohol (soft asphalt), sulphur, charring or waxlike constituents, naphthenic acids, sulphonated oils, soap, resin, or tarry constituents, the presence of which indicates adulteration or lack of proper refining. Except in oil for engines without forced lubrication, no traces of fixed oils (animal or vegetable fats) should be found.

9. In lubricating oil for main engines without forced lubrication, approved fixed oils, such as rapeseed, olive, tallow, lard, and neatsfoot oil may be used. When the above fixed oils are used, they will be well

refined with alkalies, unadulterated containing a minimum of free fatty acids, with no moisture or gumming constituents. Olive oil should not have a high specific gravity. If satisfactory emulsifying results can be obtained with straight mineral oils on engines without forced lubrication, they may be submitted for service test.

10. The *physical* tests applied to *each* oil are as follows:

(*a*) *Specific gravity:* Pyknometer; Baumé gravity.

(*b*) *Flash-* and *Fire-point:* Cleveland open cup, Pensky-Martin closed cup. The flash-point should not be below 300° Fahr., closed cup; and for steam cylinder oil not below 450° Fahr.

(*c*) *Cold-point:* The cold-point should not be above 32° Fahr., except for cylinder oils. For ice-machine oils it should be as low as possible, at least low enough for the operating condition of minus 15° Fahr. in a dense air ice machine.

(*d*) *Viscosity:* The Saybolt Universal Viscosimeter is used. The viscosity of the oils must be sufficient for the purpose intended, and, except for ice-machine oils, must not be less than 140 seconds at 100° Fahr. Viscosity is taken at 100, 130 and 210° Fahr.

(*e*) *Emulson tests:* Emulsion tests are made on all straight mineral oils, except cylinder oils. Four emulsion runs are made, using 40 c.c. of oil in each case and

1. 40 c.c. of distilled water.
2. 40 c.c. of salt water.
3. 40 c.c. of normal caustic soda.
4. 40 c.c. of boiling distilled water.

The mixture is stirred with a paddle for five minutes at 1500 R. P. M., the mixture being kept at a temperature of 130° Fahr. during the stirring and while settling out. On oils used with forced lubrication or on ice machines, the oil must completely settle out in less than 30 minutes.

(*f*) *Friction tests* are made on the Experiment Station friction machine to determine the relative friction of various oils under varying conditions of speed, bearing-cap pressures, and temperatures.

11. *Practical tests* of oils for forced lubrication are made on the Engineering Experiment Station's 75-kw. turbo-generator, making 2400 R. P. M., with the temperature of the bearing varying from 180 to 210° Fahr. Tests of ice-machine oils are made on the 1/2-ton Allen Dense Air Ice Machine. These tests cover a working period of at least 100 hours.

12. Upon the completion of the tests at the Engineering Experiment Station a service test is usually recommended on all but cylinder oils. These tests are made on ships in commission, and cover a period of several months. The oil for this test is paid for at the price of the contract oil now in use for the purposes intended.

13. Oils should be submitted as follows:

(*a*) Three oils (light, medium, and heavy) to be suitable for turbines, all forms of forced-feed or splash lubrication, dynamo engines, and all internal-combustion engines (including Diesel type). These three oils should cover the required range of viscosity. The pour-point must not be above 15° F.

FORM 1 HP

SECTION No.________

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
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(*b*) Marine-engine oil suitable for main engines without forced lubrication. This oil should form an emulsion when mixed with water, and may be either a compounded oil or a straight mineral oil. The oil must feed efficiently with wick feed, and not be washed off when mixed with water.

(*c*) An oil for use on ice machines in both the compressor and expander cylinders. This oil should not give off an objectionable odor when used with the Dense Air Ice Machine.

(*d*) Oil for steam cylinder lubrication. This oil must be a straight mineral oil.

(*e*) Oil for steam cylinders using superheated steam. This oil will be used only on shore stations and should have a high flash-point.

14. It is desired to have the trade names of the oils indicate the use for which they are submitted. For instance, "Cettus 200 Mineral" would indicate, first, the trade name, "Cettus"; second, the viscosity, Saybolt, at 100° Fahr., "200"; and, third, the kind of oils, "Mineral." For marine engines without forced lubrication, a name such as "Neptune Marine Engine" or "Atlantic Marine Engine" would indicate the use, no matter whether the oil was a compounded or a straight mineral oil. For ice-machine oils, names such as "Polar *Ice* Machine" or "Spica *Ice* Machine" will do. And for cylinder oils, such names as "Pinnacle *Mineral Cylinder*" or "600-W *Mineral Cylinder*" are suitable.

15. It is necessary that the trade name of the oil furnished the Engineering Experiment Station for the original test be the same as that furnished for service tests.

16. When the contract is awarded, the oils furnished on contract must be identical with those sent to the Engineering Experiment Station for the original acceptance test.

17. As correspondence and arrangements in connection with tests, the actual conduct of tests, and unforeseen contingencies, frequently consume many months, *prospective bidders should submit their oils* for test *eight months before they intend to bid* for Government contracts.

18. *Oils for Torpedo Lubrication* and *Torpedo Air Compressors* are under the *Bureau of Ordnance* and subject to the tests prescribed by that Bureau.

SERVICE TESTS AND GENERAL INSTRUCTIONS

1. In order that satisfactory lubricating oils may be supplied under annual contract to the whole naval service, it is necessary that certain types of oils be given actual tests in service to determine whether or not they should be contracted for.

2. The Bureau's policy amounts to the establishing of acceptable lists of lubricating oils and restricting contracts or purchases to such oils. All oils sent in for approval are passed upon by the Engineering Experiment Station, and those which would evidently be injurious or unsatisfactory are rejected. However, in the case of certain oils, service tests only will demonstrate whether or not they will give entirely satisfactory results. When service tests of oils are directed, it may be assumed that such oils will at least give fair results and will not prove injurious to machinery.

GENERAL LUBRICATION

3. There are needed three or four *oils for general lubrication.* These are really one type of oil, graded according to viscosities; ranging from the high viscosity, thick, molasses-like oil, to the low viscosity, thin, freely flowing oil. For proper identification, the contract oils are being called "extra heavy," "heavy," "medium," and "light" oils (arbitrary grading of the Bureau of Steam Engineering). Such oils must not be injurious to machinery, must separate easily when mixed with water, and must not form a heavy emulsion which will clog oil pipes. In general, the heavy oils are required where the temperature is high, for heavy, slow-moving machinery and where there would be excessive leakage of light oils in the lubricating system. Light oils are needed in cold climates, when a rapid flow of the oil is required for cooling purposes, and for small. rapidly moving pieces of machinery.

KINDS OF OIL NEEDED

4. The above "General Use" oils are intended for forced-feed and splash lubrication (turbines, gas engines, Diesel engines, aeroplane engines, reciprocating engines, etc.), and general use, except as below:

SPECIAL OILS ARE NEEDED FOR:

(*a*) *Wick- or sight-feed* lubrication systems, *where water playing on the bearing surfaces* would quickly wash away the oil and cause excessive oil consumption. In such cases a compounded "marine engine" oil is used. It contains 10 per cent. to 20 per cent. of a special oil, which forms a heavy emulsion (or lather) and sticks to the bearing surface. *This oil would quickly cause trouble and plug up the piping of a forced-feed lubrication system.*

(*b*) *Ice-machine expander and compressor cylinders.* The oil must be free from odors and remain liquid at very low temperatures.

(*c*) *Steam cylinders.* Must be a heavy oil which will stick to the cylinder walls, with a high flash-point, so it will not burn up without lubricating.

(*d*) *Hot-running torpedoes and torpedo air compressors.* Two oils provided under the Bureau of Ordnance to meet special requirements.

5. The *objects of service tests of oils* will be to determine their suitability for general service use under various conditions, including high speeds. General efficiency and oil consumption as compared with contract oils should be ascertained. Chemical and laboratory tests need not be made by a vessel, unless there are very good reasons to believe the oil is not the same as that tested at the Engineering Experiment Station. Not less than a gallon sample of oil is necessary for casual examination and test at the Engineering Experiment Station.

6. The *amount of oil needed for test* will be obtained on requisition. from the designated oil company, by the vessel. Such requisition should state: "This proprietary oil is required for special test, as directed in Bureau of Steam Engineering, letter No. .. (date ......)." The cost of the oil delivered must not exceed the cost of similar contract oil.

7. The *report of the service test* should cover not less than 10 days' steaming, and, as far as possible, show the following:

Amount of test oil used.
Number of hours oil was used.
Average speeds of machinery.
Maximum and average temperature of bearings.
Maximum and average temperature of oil in system.
Average pressure carried on oil pumps.
Gallons of oil per hour ordinarily pumped through system.
Temperature at which oil is boiled out and amount of water drawn off.
Oil consumption as compared with the ordinary oil.
Unusual conditions or attendant circumstances.

NOTE. On twin-screw vessels, the test oil is generally tried on one engine and contract oil used on the other. When a test oil is considered unsatisfactory, five-gallon samples of both the used and unused oil may be required sent to the Engineering Experiment Station for further test and report.

Also see index for other Government specifications as issued by the Committee on Standardization of Petroleum Specifications.

SECTION 10dd

OIL SWITCHES AND CIRCUIT BREAKERS

OIL SWITCHES (ELECTRIC)

The duties of oil switches are very important, and they may be called upon to operate under conditions that are much more severe than are met with in other high-voltage electric apparatus. Great losses may follow the failure of oil switches to operate, and for this reason their construction, and the oil supplied to them, must be carefully considered.

FIG. 1. SEC. 10*dd*.—Triple-pole, single-throw, 15,000-volt, 2000-ampère oil-break switch. (Made by the General Electric Company.)

Fig. 1, Sec. 10dd, shows a triple-pole, 15,000-volt, 2000-ampère oil break switch made by the General Electric Company. The oil vessels for a switch such as this one are 8 inches in diameter and hold 12 gallons of oil.

Fig. 2, Sec. 10dd, shows a section of an oil vessel and the oil baffles that are placed in it, to prevent the throwing of the oil, when the switch is opened. One of these baffles is used in each oil vessel of the switch. This switch is made by the General Electric Company, and a description

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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of its operation is as follows: When the electric circuit is opened by pulling the switch, a movement is imparted to the oil, due to the expansion of the gases formed by the arc. The baffle checks this oil movement in such a manner that the gases are allowed to separate from the oil and to escape from the oil vessel through a vent in the top. The oil is forced back into the area of the breaking arc and shortens the time of breaking the arc. The baffle does away with the tendency of the oil to dash from the top of the oil vessel.

FIG. 2. SEC. 10*dd*.—Oil baffle and section of oil vessel of the oil switch, shown in Fig. 1, SEC. 10*dd*.

FIG. 3. SEC. 10*dd*.—Oil circuit breaker with two-coil overload trip in open position, tank removed.

Oil for use in the oil switches must possess a high resistance to carbonization and must also have a good flashing point. It should have a fairly low viscosity to permit of its quick flow towards the arc. The oil must be free from moisture, acid, alkali, or sulphur.

OIL CIRCUIT BREAKERS.—Fig. 3, Sec. 10dd, shows views of small capacity industrial oil circuit breakers, as manufactured by the General Electric Company. There is a line shown on the outside of the tank, which indicates to what depth the tank should be filled with oil.

The oil used for these switches must be free flowing, filtered, free from moisture, and, in general, the same principles apply as in the case of the other oil-switch oils.

SECTION 10ee
PNEUMATIC TOOLS

GENERAL.—The keynote of the successful operation of pneumatic tools is cleanliness and efficient lubrication. The tools should only be used for the purposes for which they were designed. The air used should be given attention, and, wherever possible, the air should be drawn from the outside, where it is apt to be clean and cool. A strainer should be placed over the inlet. An inlet may be made by using wire netting, over which one or two layers of muslin have been placed. A strainer will be a great help in the elimination of lubrication troubles. A strainer should also be placed in the pipe lines leading to the tools, and special strainers are manufactured for insertion between the pneumatic tool and the hose nipple.

Valves and pistons for both hammers and drills require a free-flowing, low cold-test oil. The compressed air tends to drive the oil away from the parts with which it comes into direct contact. These parts should be freely lubricated about once an hour.

It is difficult to impress the ordinary hammer and drill "runner" with the importance of oiling the drills before they actually run dry. Often the parts will freeze fast and break, due to lack of lubrication.

In large plants "an oiler," or "grease-gun man," visits the various machines and renews the oil or grease at frequent intervals. A "grease gun" in the form of a metal syringe is usually used to inject the lubricant into the machines where grease is used.

The internal parts of compressed-air machines, such as drills, riveters, mining machines, compressed-air locomotives, etc., are usually small in size and operated at very high speeds.

DRILLS

ROTARY AIR DRILLS.—The gears and crank-cases of such drills as the "Little Giant" (see Fig. 1, Sec. 10ee) will operate best with a semi-fluid lubricant of about the consistency of vaseline. The compressed air does not come into contact with these parts. The grease may be forced into the crank-cases with the aid of a grease gun, through the dead-air handle. Usually a filling every 10 hours will give good results. The lubricant used must have no tendency to churn up into a foamy mass. The crank-shaft, operating in the "Little Giant" drill, carries sufficient grease into the cylinders. A small quantity also works around the drill spindle. It requires about a pint of grease to fill the casing.

All "Little Giant" drills and reversible machines are made after a standard design and pattern. These machines are of the balanced-piston type, and consist of four single-acting cylinders, arranged in pairs, each pair of pistons being connected to opposite wrists of a double crank-shaft. In the improved type, the bearings of the crank-shaft have been made of the ball-bearing type. All of the four cylinders open at their rear ends into an enclosed chamber. When the machine is in use, the rapid rotation of the crank throws the lubricant that is in the case over the parts. The exhaust air does not pass through the working parts, thus eliminating the possibility of dirt being carried into the parts with the air.

FIG. 1. SEC. 10ee.—Working parts Little Giant air drill. (Courtesy Chicago Pneumatic Tool Co.)

Fig. 2, Sec. 10ee, shows a part section of the "Little David," reciprocating pneumatic drill, made by the Ingersoll-Rand Co. The connecting rods run on roller bearings. The crank-shaft works in ball bearings. The crank-shaft and gears revolve in dust-proof chambers. These should be filled with a semi-fluid grease of the consistency of vaseline. The grease may be inserted in the machine through the crank-cap by removing the plain, or dead, handle.

The "Little David" Pistol-Grip Drill should have a special lubricator made by the manufacturers, inserted in the hose line about two or three feet from the tool.

ROCK DRILLS.—Almost all drills are subject to freezing troubles. This is due to the moisture in the air and the narrow winding passages the exhaust must travel in order to escape to the atmosphere. Dirt in the air often causes the drill to work badly, and may even stop it.

Fig. 3, Sec. 10ee, shows a sectional view of a "Sergeant" rock drill,

showing the valve mechanism. This drill is manufactured by the Ingersoll-Rand Company.

Fig. 4, Sec. 10ee, shows a sectional view of a Leyner-Ingersoll drill. The method of lubricating this type of drill is as follows: An oil chamber is cast beneath the cylinder bore, between the sides of the guide shell.

A plugged opening at the top of the cylinder provides a means of filling the oil chamber with oil.

Small passages are provided between the oil chamber and the cylinder bore. The oil and air in the chamber are thus placed alternately under running pressure and exhaust pressure.

FIG. 2. SEC. 10*ee*.—Little David air drill.

A small amount of the oil is thus fed to the cylinder bore at each stroke of the piston.

THE BUTTERFLY VALVE.—This type of valve, which is used in the Leyner-Ingersoll and other Ingersoll-Rand types of drills, is an independent valve, since it has no connection with the "hammer."

The valve is an "air thrown" valve, being operated by unbalancing the air pressure. It consists of a single piece of steel, shaped to form a cylindrical trunnion with two flat wings, one on each side.

The trunnion is carried in a bore in the valve chest, and the wings are accommodated by a longitudinal groove in the valve chest, which allows

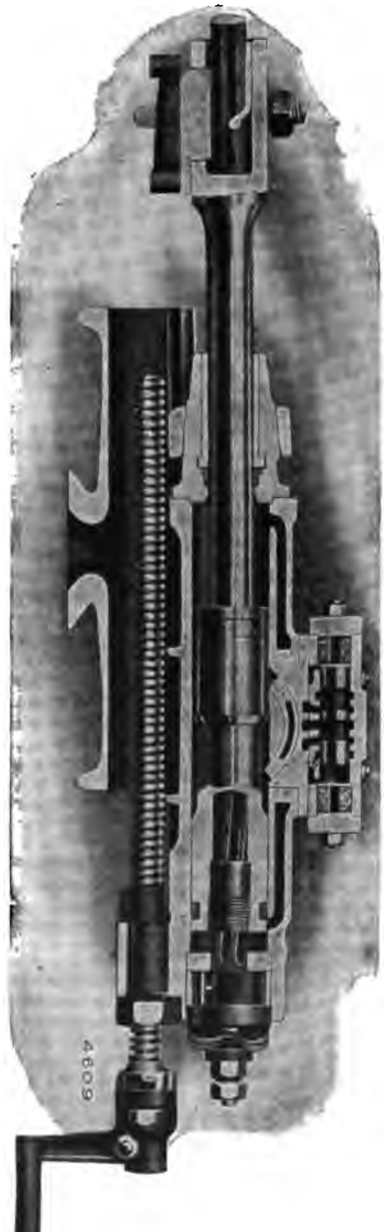

FIG. 3. SEC. 10ee.—Sectional view of Sergeant rock drill, made by the Ingersoll-Rand Company.

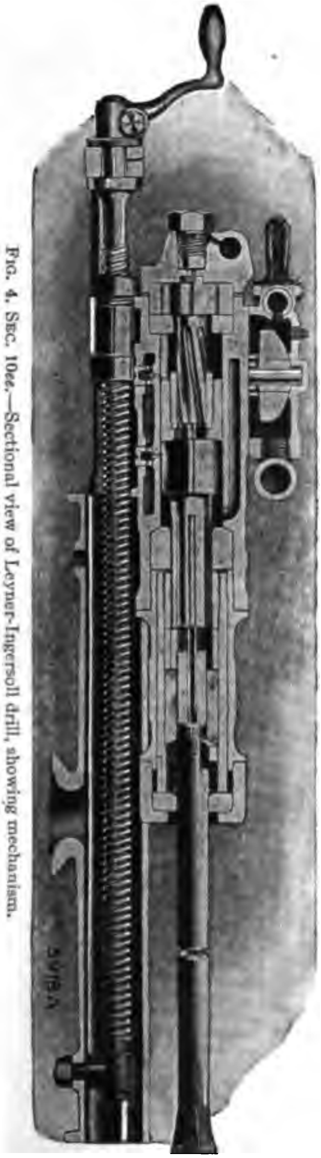

FIG. 4. SEC. 10ee.—Sectional view of Leyner-Ingersoll drill, showing mechanism.

of a slight back-and-forth rotative movement. This movement is obtained by the unbalancing of the air pressure on each of the wings alternately.

Fig. 5, Sec. 10ee, shows a butterfly valve and chest.

There is a separate and distinct passage for the air supply and exhaust to each end of the cylinder. This style of valve movement results in a very high-speed drill.

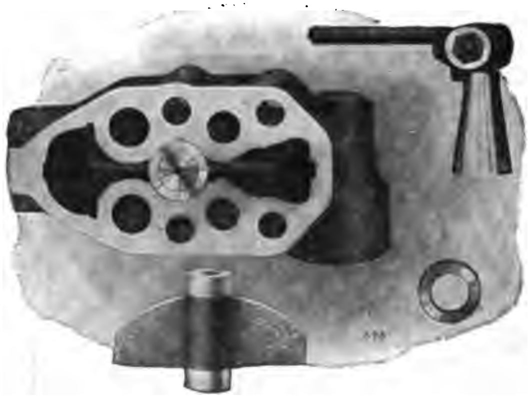

FIG. 5. SEC. 10*ee*.—Butterfly valve and chest of Leyner-Ingersoll drill.

LUBRICATION.—Lubricating oils for use in compressed-air machinery should have a low cold test. The expansion of air from high to low pressures causes it to absorb heat from the metal parts surrounding it, and intense cold is produced in these parts.

A good oil for use on pneumatic drills and hammers, etc., would have the following general specifications:

(*a*) Viscosity .... 150 to 200 at 100° Fahr. (P. B.).
225 to 250 at 100° Fahr. (A. B.).

(*b*) Cold test ....Not above 10° Fahr.

HAMMERS

HAMMERS.—Fig. 6, Sec. 10ee, shows a sectional view of a "Little David" chipping hammer. There are two parts to the valve movement, the valve and its guide. A strainer is located in the valve chamber for removing dirt and grit.

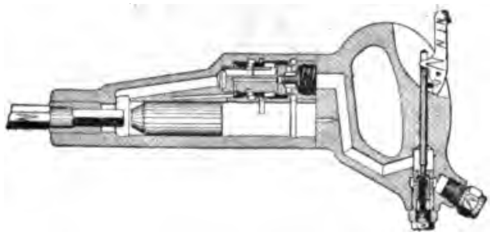

FIG. 6. SEC. 10*ee*.—Little David chipping hammer.

Fig. 7, Sec. 10ee, shows a sectional view of the "Little David" valveless scaling hammer. This tool is valveless, so that there is but one moving part in the barrel of the tool, which is the piston.

For the lubrication of these tools a light, low cold-test oil should be poured into the inlet in the handle (where the hose connects) every two or three hours. A thick or gritty oil will cause the parts to cut or wear, or work sluggishly. The entire tool should be taken apart at least once a week, when in constant use, cleaned with kerosene and oiled. The oil should have viscosity Saybolt at 100° Fahr. of 100–110 (P. B.) or 120–125 (A. B.), and a low cold test.

Many careless operators will allow their tools to get so dirty that they will stop due to dirt, rust, or gummed oil.

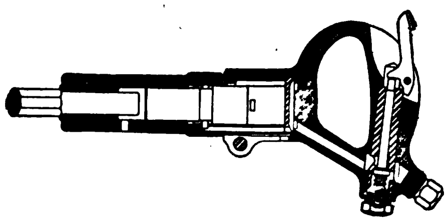

FIG. 7. SEC. 10*ee*.—Little David valveless scaling hammer.

Fig. 8, Sec. 10ee, shows a "Little David" Ingersoll-Rand calking machine. Liquid petrolatum is recommended for the lubrication of these tools.

For the lubrication of the Ingersoll-Rand coal pick and ore picker, use an oil of 100–110 Vis. Saybolt at 100° Fahr. (P. B.) or 120 (A. B.).

For the "Little David" jam riveter, use the same oil as above.

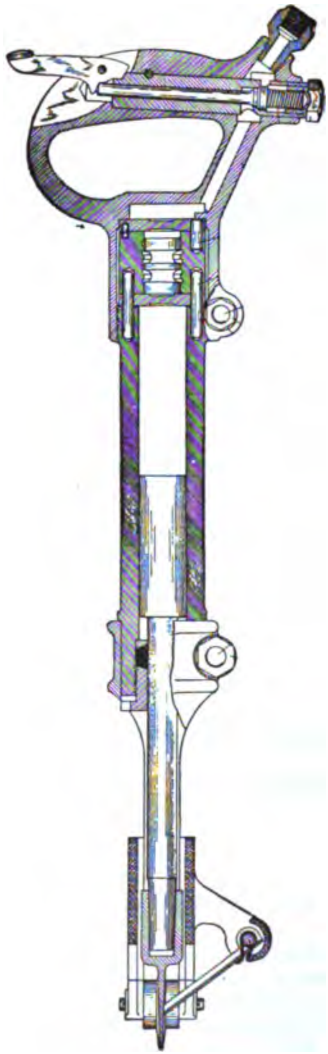

FIG. 8. SEC. 10ee.—Little David, type 13, calking machine.

FORM 1 HP

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RECOMMENDATION AND PRICE SHEET

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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 EB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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OILERS

PNEUMATIC AUTOMATIC OILERS.—Fig. 9, Sec. 10ee, shows a Chicago pneumatic oiler, for use in connection with pneumatic tools. It is used with all classes of air hammers, rock drills, Boyer & Keller piston drills and rotary drills.

Fig. 9. Sec. 10*ee*.—Chicago Pneumatic Tool Co. automatic oiler for use with pneumatic tools.

Referring to the figure, the oil chamber is located in the centre and the flow of oil is governed by means of a pin valve. The air passes around the air chamber, and a small volume passes through the needle valve, operating on the principle of an atomizer. Thus the flow of the lubricant can be regulated, the air carrying the lubricant to the different parts with which it comes into contact.

SECTION 10ff

PRINTING PLANTS

HIGH-SPEED PRESSES

HIGH-SPEED PRESSES.—For high-speed presses, such as the Kelly press, use an oil of 175–190 Vis. (P. B.) or 200 Vis. (A. B.), or a semi-fluid grease of one-fourth consistency. As an illustration of the speeds made with this type of press, the Kelly press makes 3600 impressions per hour, and at this speed the cylinder makes 7200 revolutions per hour. Better results can be obtained with a one-quarter consistency semi-fluid grease on these presses than can be obtained with an oil.

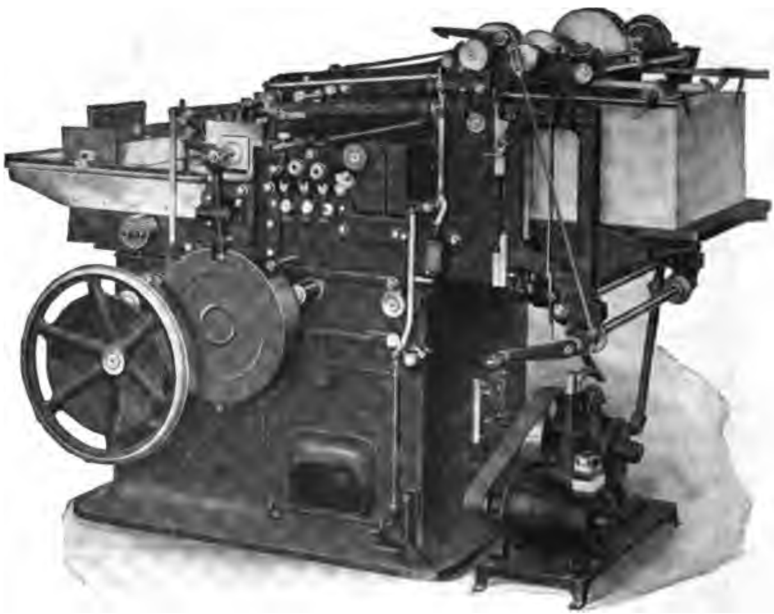

FIG. 1. SEC. 10*ff*.—Kelly press and automatic feeder.

There are several compression grease cups on the Kelly press, which should be supplied with a No. 3 cup grease.

The impression rollers run in a lubricating well under the bed. There are felt pads supplied here, which rub against the rollers. These pads should be saturated once every two weeks with lubricant. The grade of semi-fluid lubricant, as above described, will give satisfactory results with these pads.

For the racks and gears and the working surfaces of the cams, use a No. 3 cup grease.

A view of the Kelley press and automatic feeder is shown in Fig. 1, Sec. 10ff.

PRINTING INKS.—The perfecting of paper making and development of rapid-printing presses have brought into use several rather distinctive types of ink. Linseed oil, due to its property of quick drying on exposure to the air in thin films, adhering very firmly to paper and not readily affected by further exposure to air and light, is used as a vehicle in the better-grade inks. Corn oil, rapeseed oil, etc., classed as semi-drying oils, are used when linseed oil cannot be obtained at a reasonable price. Resin, which is readily melted, is added to the oil in preparation of printing ink. Resin oil, produced by distillation of resin, is extensively used in inks, particularly cheap inks. Its value lies in its rapid drying by absorption, readily penetrating soft papers. When mixed with resin and suitable driers, generally organic salts of lead and manganese, it possesses some drying properties. It has been demonstrated that when resin oil and resin, are used as a substitute for linseed oil, it may cause trouble, just as linseed oil has been found objectionable, when used to replace resin oil, in inks demanding rapid absorption. For special inks, where a hard glossy finish is required, hard gums, such as copal, dammar, and kauri, are used. They do not tend to crack as ordinary resin. Some heavy petroleum oils, vaseline, asphalts or bituminous products are used in inks.*

Web-press inks for newspaper work have as a vehicle usually mineral oil, resin oil, resin and soap (the metallic salts of fatty and similar organic acids) with a pigment of cheap lampblack and possibly some blue dye.

For book printing, soap is added, to allow the inked type to be withdrawn from the moist paper, without smearing or adhering. Hempseed, poppy or nut oil sometimes replace linseed oil.

Linseed oil as it comes from the press contains a large amount of sediment, or "foots," which must be removed when the oil is to be used for printing-ink varnish. Raw linseed oil or boiled oil will instantly sink into paper, leaving a greasy stain, and the oil must be altered to prevent such penetration. This is done by boiling or burning to make linseed varnish. Burnt oils are usually called plate oils, being used in preparation of engravers' ink. Linseed varnishes made by burning are "shorter" (slight cohesion) than those made by boiling.

PLATE PRESSES

PLATE PRESSES.—Typical presses of this type are the Cottrell, Miehle, Premier, Hodgeman-Huber, etc.

The proper method of lubricating these presses is to start oiling at the motor, or pulley, shaft, and to proceed along the side of the press, thence around the fountain end, down the feeder side and across the back to the starting point.

Cylinder bearings, vibrator pinion gears, roller sockets, plunger leathers, gripper-rod connections, etc., should be lubricated three or four times per working day.

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* Note. In the preparation of printing inks, frictional heat, generated by the power exerted between the rollers of the ink-grinding mill, is conducted to the printing materials. The decrease in viscosity or body of ink liquid must, therefore, be considered while it is in the mill.

A typical plate press has gears running at 1900 R. P. M., there being two revolutions for each impression, one to "deliver" and one to "print." The cylinder bearings are equipped with open slots. On the main bearings two pipes lead to the inside of the box of the main driving shaft for oiling purposes. There is usually wicking at the wells at these points.

The bed of the press passes on way-frame steels and their guides. The guides have four pockets at their extremities, which are intended to catch and hold the surplus lubricant.

The airheads, which are intended to take up the shock, at each end on the bed travel, move in and out of air chambers. The heads are provided with a leather cup, which seals the chamber. Usually neatsfoot oil is recommended for the airheads, in order to preserve the leathers.

The points requiring lubrication on these presses and the proper lubricants are as follows:

For the cylinder bearings, use an oil having 275 Viscosity for (P. B.) and 350 Viscosity for (A. B.), or a semi-fluid grease of five-eighths consistency. For the way-frame steels, guides, eccentric and eccentric block, roller sockets, gripper-rod connections, pinion gears, etc., use the same lubricant.

For the airheads, use neatsfoot oil, or a high-grade semi-fluid grease. For the ring oilers of the electric motor, use the oil as recommended under the section on Motors.

For lubricating the gears, use a No. 4 cup grease.

NEWSPAPER PLANTS

BRIEF OUTLINE OF NEWSPAPER PRINTING.—The operations of printing a newspaper are rather confusing to the average oil man who enters one of the large city newspaper plants, and in order that the oil trade may have a clear understanding of the purposes of the various machines met with in these plants, the following brief description is given:

After the "copy" is written and edited by the Editorial Department, it is sent to the Composing Room, where it is cut into pieces, called "takes"; these are distributed to the operators of the "Linotype Machines" and set in lines of type called "slugs" and delivered to the "make-up" stones, or steel-top benches. Here the stories, newsmatter of all sorts, advertisements, and half-tone cuts are assembled and locked into steel frames, called "chases." The "chases" are then delivered to the stereotype department and a "matrix," which is made of several thicknesses of blotter and tissue held together with paste, the principal ingredients of which are clay, chalk, and gum arabic, is laid upon the face of the type. It is then covered with a heavy wool blanket and rolled under a large steel roller, which mashes the soft, damp "matrix" into the type form. The "form," with the "matrix" still covering its face, is then placed under a "steam table," which is a table that holds the "matrix" firmly imbedded in the type form and bakes it with live, dry steam into a permanent brittle consistency.

The "matrix" is next placed in a cylindrical casting box and becomes the face of a mould, into which molten metal composed of lead, tin, and antimony is pumped. When the metal has solidified, the curved plate resulting is trimmed and shaved to the proper thickness and is ready for the

press. The machine used by most of the metropolitan newspapers to produce these plates is the Junior Autoplate Machine.

The plates are locked onto the cylinders of the presses in pairs, making a complete cylindrical surface and producing two completed papers for each revolution of the presses, which print from a " web " and deliver the papers, folded to half size, at the rate of from 20,000 to 40,000 per hour.

The presses are driven by variable speed motors, ranging from 40 to 80 H. P., through a series of gears, off the main shaft.

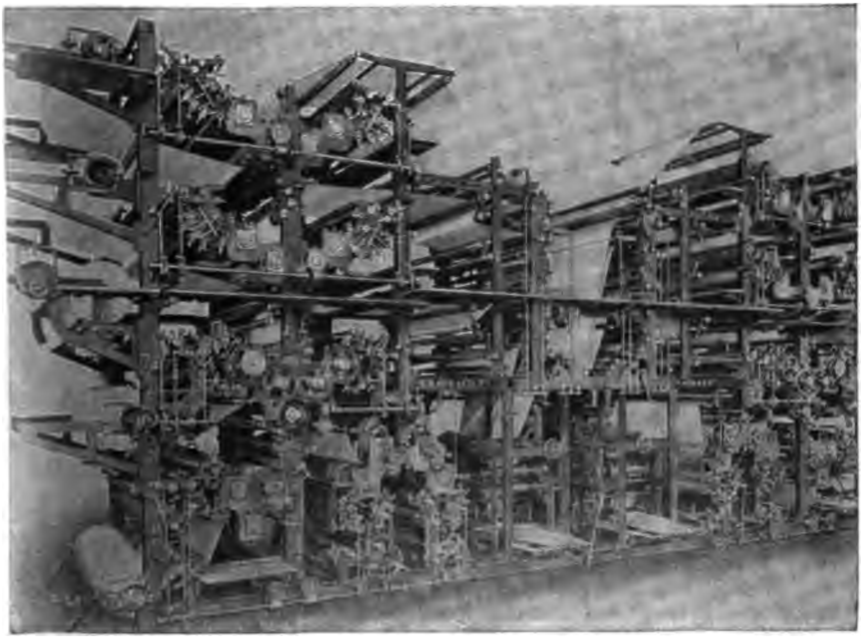

FIG. 2. SEC. 10ff.—High-speed, octuple newspaper printing press, made by R. Hoe & Co.

The plate and impression cylinders are carried on 3 1/2-inch to 4-inch journals, with bearings on both ends. The journals are of steel, and the bearings are made of brass or phosphor bronze, and are about six inches long. The bearings have oil grooves cut in the upper half.

The cylinder bearings are the most important bearings, from a lubricating standpoint, about the presses. The cylinders weigh about 1200 to 2000 pounds apiece, and each plate (there are eight plates to a cylinder) weighs about 60 pounds.

A standard, high speed octuple press is shown in Fig. 2, Sec. 10ff, through the courtesy of R. Hoe & Co., of New York.

The gears and other quick-running mechanisms are clearly shown in the cut. The motors are placed in a pit below the press.

Ink is furnished to the printing plates from a fountain or reservoir, on one side of which is a steel roller. This roller is driven by a ratchet and pawl, and the quantity of ink carried on each revolution is determined by a scraping blade parallel with the roller, the clearance of roller and blade being adjustable by a series of thumb-screws. The ink is transferred from the steel roller to a series of soft composition rollers, which in turn spread a thin film of ink onto the printing plates. Evenness of color is accomplished by vibrating rollers, which are worked by cams. These cams are not enclosed and require continual oiling.

LUBRICATION.—(*a*) For the cylinder bearings a heavy red engine oil having the following general specifications should be used freely:

* 400 to 500 Vis. at 100° Fahr. (P. B.), or 700 to 750 Vis. at 100° Fahr. (A. B.).

(*b*) For the cams on the vibrating rollers, a very light filtered cylinder stock of about 130° Vis. at 212° Fahr. may be used, or a medium-bodied semi-fluid grease.

(*c*) For the bevel gears at the motor and the cylinder gears on the side, a medium-bodied gear grease should be used (see index).

(*d*) For the motor bearings, a neutral machine oil of about 160 Vis. at 100° Fahr. (P. B.), or strictly non-emulsifying oil, of about 200 Vis. at 100° Fahr. (A. B.).

(*e*) For the worm gear, use a dark cylinder oil of about 140 to 150 Vis. at 212° Fahr., or the same oil as recommended for the cams may be used.

(*f*) For the auto-plate machine, where the temperatures are high, use a filtered cylinder oil as outlined under (*b*).

(*g*) For linotype machines, use a light-bodied oil as outlined under (*d*).

(*h*) For the monotype machines, which are usually lubricated with a suet, a fibre grease of high melting point is recommended.

PRINTING AND PUBLISHING INDUSTRY IN U. S.—Government statistics give 34,000 as the total number of firms or establishments engaged in printing and publishing in the United States. Conservative estimates place the consumption of gasoline and benzine at 330,000 gallons. Each of these plants operate trucks with an estimated gasoline consumption of 2,500,000 gallons. Seventeen million gallons of "wash-up liquid" are consumed, and over 3,000,000 gallons of lubricating oils.

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* A semi-fluid grease of three-eighths the consistency of vaseline will give excellent results.

FORM 1 HP

SECTION No.____

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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
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SPECIAL OILS

ROLLER WASH.—It is necessary to swab off the ink rollers frequently with a light petroleum distillate of about 115° to 130° Fahr. flash test, to prevent the dust from the paper and dirt, which accumulates upon the rolls, making them sticky and causing the paper to adhere to the plates.

This wash is usually applied with a rag, and it should be of such a nature that it will not dry too quickly, and yet it must have good degreasing properties, particularly when it is also used as a wash for the plates. The wash must evaporate completely and must not leave any greasy oil on the roll, since that would cause uneven ink distribution to the plates, with resulting poor impressions. Ink rolls are made of rubber and glycerin, and the roller wash must not cause them to harden.

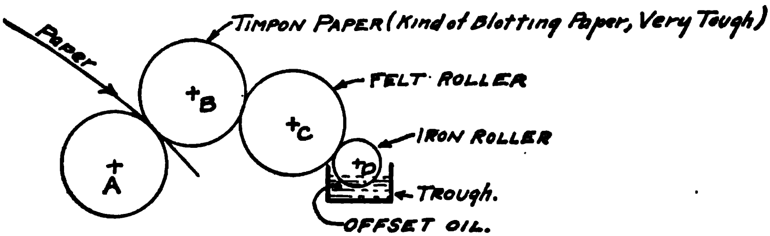

Fig. 3. Sec. 10*ff*.—Offset oil application.

OFFSET OIL.—When printing matter, such as pictorial sections, etc., the sheets of paper would ink up onto the succeeding sheets if the surplus ink was not rubbed off. Fig. 3, Sec. 10ff, shows how offset oil is used to prevent this. Referring to the figure, *A* is a plain roller, *B* is a roller covered with a sort of blotting paper, called "timpon paper," to absorb the ink. This paper is tough. *C* is a felt roll to take off the surplus ink. *D* is an iron roller, used to keep the felt roller moist with offset oil, which the iron roll carries from the tank, as shown.

A typical offset oil can be made by blending about 95 per cent. of water white, 150° oil (kerosene), with about 5 per cent. of a light filtered cylinder stock. Some plants use a pale oil of about 100 viscosity at 100° Fahr., instead of the kerosene oil, and 5 per cent. of carbon tetrachloride may be added to the formula.

SECTION 10gg
RAILWAYS

THE RAILROAD DOLLAR.—It is spent thus in cents and fraction of cents:

Labor	44.05
Coal and oil	8.64
Material, supplies	9.80
Miscellaneous expenses	4.66
Taxes	4.14
Loss and damages	2.26
Betterments, etc.	4.57
Interest on funded debt	13.04
Rents of leased roads	3.92
Dividends and surplus	4.92
Total	100.00

CAR JOURNALS

RAILWAY CAR JOURNALS.—The journal boxes of car journals are packed as shown in Fig. 1, Sec. 10gg. The packing is first made into a roll and packed tightly around the back of the box to retain the oil and exclude dust. The rest of the box is packed with loosely formed packing, placed sufficiently firm underneath the journal to prevent its settling away, due to the shocks and jolts produced as the truck moves along the track. The packing should never extend above the centre line of the journal. In the front end of the box a separate piece of packing should be placed, extending not more than a half inch above the lower edge of the journal collar. This packing serves to hold the other packing in its position under the journal.

STANDARD JOURNALS.—Adopted by the Master Car Builders and Master Mechanics' Association, 1913:

Type	Journal inches	Distance between hubs (inches)	Distance between centres of journals	Max. cap. pounds	Approximate weight
A	3¾″ x 7″	47⅝″	75″	15000	420
B	4¼″ x 8″	47⅝″	75″	22000	520
C	5″ x 9″	47⅝″	76″	31000	680
D	5½″ x 10″	47⅝″	77″	38000	830
E	6″ x 11″	46″	78″	50000	1000

The dimensions of the above journals will be of value in the calculation of mileage contracts.

Fig. 2, Sec. 10gg, shows a standard type of railroad journal. The main causes of hot boxes on these journals are as follows:

1. Improper lubrication, caused by conditions as noted in a later section.

2. Rough journals, which may be caused by seams in the journals, due to flaws, and cut journals, caused by hard spots in the bearings.

3. Bad journal bearings, caused: (*a*) Bad alloys in metal, resulting in hard and soft spots. (*b*) Worn-out bearings. (*c*) Distorted bearings allowed to run too long. (*d*) Too much lead used in the composition.

4. Overloaded cars cause many hot journals by making the load per inch too high.

5. Trucks that are not kept perfectly trued-up.

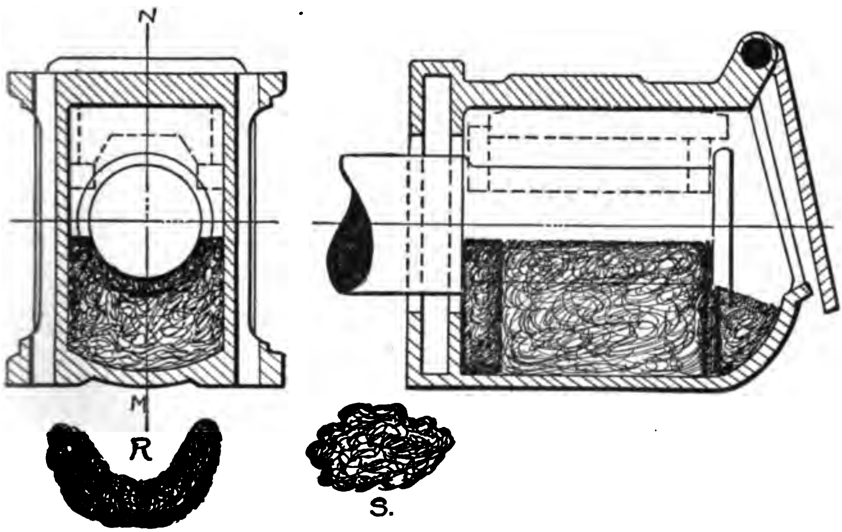

FIG. 1. SEC. 10gg.—Method of packing railway car journal boxes.

6. Improper loading of cars; this particularly is found in baggage cars.

7. Broken brasses and wedges.

8. End wear on brasses, causing babbitt to move and preventing oil getting under the bearing.

9. Loose covers and resulting grit.

10. Packing getting outside of the journal collar.

11. Journal keys not fitting.

12. Arch bars not properly aligned in box or on the brass.

13. Flat spots on wheels, resulting in pounding.

OTHER CAUSES OF POOR LUBRICATION ON JOURNAL CAR BOXES.—

(*a*) The waste may have insufficient oil in it.

(*b*) There may not be enough waste in the cellar.

(*c*) The waste may not be resilient.
(*d*) The waste may not be evenly saturated with oil.
(*e*) The oil may have been washed out of the cellar by rain.
(*f*) The oil may have frozen, which would stop the feed.

CARE OF JOURNALS.—The packing should be stirred up and examined at each interchange yard. The brasses should be examined for end wear, and examination should be made to determine whether the babbitt has moved, or is hanging on the side of the brass, preventing the oil from getting under the bearing.

FIG. 2. SEC. 10gg.—Standard type railroad journal.

The packing in all journal boxes must be frequently loosened on each side of the journal, to prevent the same surface of the packing from remaining in contact with the journal too long, and becoming covered with a hardened, glazed surface, which would prevent the proper feeding of the oil to the bearing. Special tools are designed to enable the inspector to carry out these loosening, or turning, operations.

JOURNAL SPEED.—The surface speed of a 5 1/2-inch journal, when the car is traveling at 70 miles an hour, is 1500 feet per minute. To appreciate this condition, we can compare it with a high-speed turbine, in which the surface speed is about 1000 feet per minute.

STANDARD SPECIFICATIONS FOR WASTE

WOOL WASTE.—This waste shall contain no other fibre than wool. It must be well machined and free from moisture, sweepings, flyings, and dirt.

Wool waste must be all-wool carpet yarn, and the threads must not be less than three inches long. The waste must contain at least 80 per cent. of new wool.

COLORED COTTON WASTE.—This waste shall contain no other fibre than cotton. It must be well machined, free from moisture, sweepings, flyings, and dirt.

This waste shall be composed of a mixture of colored and white cotton threads in equal parts. The threads shall not be less than three inches in length.

No material shall be used in the manufacture of this waste, which is not new, or which shows evidence of having been soiled, washed, and cleaned.

WHITE COTTON WASTE.—This waste shall contain no other fibre than cotton. It must be well machined, free from moisture, sweepings, and dirt.

Only new white cotton threads may be used, and their length must be at least three inches. No cotton that has been soiled and washed may be used.

The gross weight will be paid for subject to the following provisions: The weight of the wrappings and hoops not to exceed 6 per cent. of the gross weight. The moisture not to exceed 3 per cent. of the gross weight. Any excess of the above weights up to 3 per cent. will be deducted from the payments, at the same price per pound as the purchase price of the waste.

If the moisture exceeds 6 per cent. the waste will not be accepted.

PREPARING WASTE FOR USE.—Railroad waste is prepared at a central distributing point, and is delivered to the oiling stations ready for use.

The usual method of preparing the waste is as follows: It is first immersed in the oil for two days. The waste is then placed in thin layers on wire racks and allowed to drain until it contains about 4 3/4 pounds of oil per pound of dry waste (approximately five pints).

The preparation should be carried on in a room, the temperature of which during the cool weather, is about 70° Fahr.

PACKING TOOLS

PACKING IRONS.—In order to aid in the turning of packing and repacking the boxes, suitable tools must be provided.

Fig. 3, Sec. 10gg, shows a curved form of packing iron, designed to aid packing directly under the journal, since this part of the box must be packed more firmly than on either side of the journal, to prevent settling away of the packing.

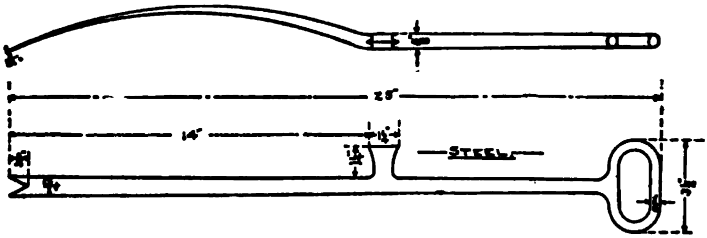

FIG. 3. SEC. 10gg.—Packing tool for journal boxes. Curved type.

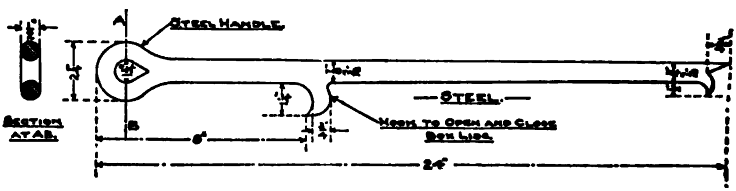

FIG. 4. SEC. 10gg.—Tool for loosening packing of journal boxes in railway yards.

Fig. 4, Sec. 10gg, shows a tool designed for yard use, to give a quick method for keeping the top portion of the packing on each side of the journal in an elastic condition, and to prevent glazing of the waste and the resulting stoppage of oil feed to the journal. This glazing effect may even produce a wiping action on the journal surface. The hook and spur on the end of the tool are intended to provide, by means of the hook, a method of removing surplus packing and loosening the packing on the journal sides, and by the use of the spur to replace the packing to the back end of the box, or to add new packing.

LOCOMOTIVES

GENERAL.—Excluding such work as switching, logging and industrial, the majority of locomotives are used in road service, and this service may be divided into two general classes—passenger and freight. For heavy work, the locomotive is required to exert a high tractive force at comparatively slow speed. For fast passenger service, the tractive force is low, while the speed is high.

Locomotive horse-power is measured by the product of tractive force and speed, and it is, therefore, frequent for a passenger locomotive to develop as much horse-power as a freight. The hauling capacity of a locomotive depends primarily upon its weight, as carried upon the driving wheels.

ARTICULATED LOCOMOTIVES.—In cases where great tractive force is required, an "articulated locomotive" is used. This type of engine has two or more sets of frames, which are connected by hinges. The driving wheels are divided into as many sets as there are frames. The wheels of each set are rotated by a separate pair of cylinders. By this design a large number of driving wheels may be used. The type of articulated locomotive that is in most common use is the "Mallet." It has two sets of driving wheels. It is operated compound, and has two high-pressure cylinders and two low-pressure cylinders. The high-pressure cylinders driving the rear set of wheels and the low-pressure driving the forward set of wheels. Mallet locomotives are built with from two to five pairs of driving wheels in each set, or group, and sometimes have in addition front and rear trucks.

SUPERHEATERS.—The type that is in most common use for locomotive work is known as the firetube type. It usually gives about 200° Fahr. superheat to the steam. It consists of a header, placed in the smoke-stack, and divided with two (2) compartments, one for saturated steam and one for superheated steam. Pipes connect the two compartments, through which steam flows while passing from the throttle valve to the cylinders.

The superheater pipes are placed in a number of large tubes, which convey the products of combustion from the firebox to the smokebox. Usually a double loop of superheater pipe is placed in each large tube. Thus the hot gases passing through the large tubes heat the water around the tube and at the same time heat the steam inside of the small tubes.

COMPOUNDING.—To increase economy, compound cylinders are sometimes used. The principle types of compounds in the United States are: 1. The four-cylinder or Vauclain type, having one high- and one low-pressure cylinder on each side. One cylinder above the other and the two piston rods on each side connected to the same cross-head. 2. The cross-compound type, which has a low-pressure cylinder on one side and a high-pressure cylinder on the other side. 3. The tandem-compound, which has one high-pressure and one low-pressure cylinder on each side, set with the high-pressure cylinder ahead and both pistons having a common rod. 4. The balanced-compound, which has two high-pressure cylinders, set between the frames and driving through a crank-axle. The two low-pressure cylinders are set outside in the usual way. The two crank-pins on the same side of the engine are set 180° apart, so that the reciprocating parts

act against each other. This type is usually found in high-speed use. 5. The articulated triplex compound, which has two high-pressure cylinders and four low-pressure cylinders. This type has three sets of drivers. 6. The articulated Mallet compound. This has the high-pressure cylinder driving one set of wheels and the low-pressure driving the other set.

SPECIAL DEVICES.—To lessen the labor required to operate large engines, there has been developed several devices, as follows: (*a*) Mechanical stokers. (*b*) Power-operated fire doors. (*c*) Power-operated grate shakers. (*d*) Coal pushers on the tender for moving the coal forward in reach of the firemen. (*e*) Power-reversing gears.

FUEL AND WATER.—Ordinary results indicate that a locomotive will consume about 4 pounds of coal and 28 pounds of water per horsepower hour.

FORMULAS.—1. to obtain the revolutions of the wheels per minute:

$$\text{R. P. M.} = \frac{M \times 28}{D}$$ Where M equals the speed, miles. Where D is diameter wheel, per hour.

2. To obtain revolutions per mile:

$$\text{R. P. Mile} = \frac{1680}{D}$$ Where D is diameter of driving wheel in feet.

3. To obtain the piston speed in feet per minute:

$$\text{Piston speed} = R \times 2S$$ Where R is the revolutions per minute, and S is the stroke of the piston, in feet.

LOCOMOTIVE LUBRICATION

OIL CUPS.—Fig. 5, Sec. 10gg, and Fig. 6, Sec. 10gg, show two forms of locomotive oil cup. One cup is the Loose wire-feed type for crank-pins, and the other cup is used on the main and side rods.

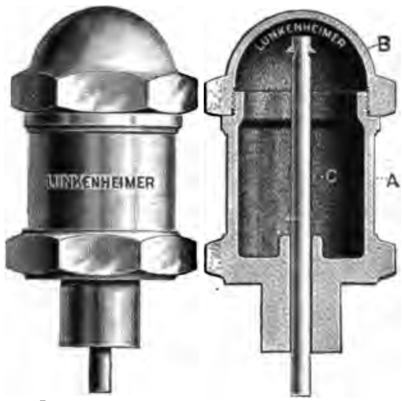

Fig. 5. Sec. 10gg.—Plain locomotive crank pin oil cup with loose wire feed.

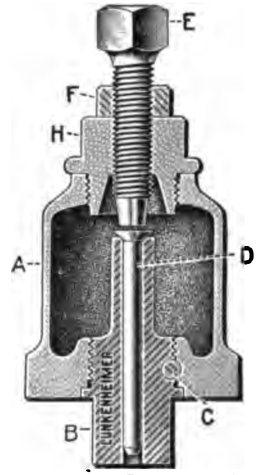

Fig. 6. Sec. 10gg.—Lunkenheimer locomotive main and side rod oil cup. The feed is regulated by movement of rod *D*, which operates a valve. The lift of the valve is limited by the screw *E*.

See page 853 for Locomotive Grease Cups.

LOCOMOTIVE CYLINDER LUBRICATORS

MICHIGAN CYLINDER LUBRICATORS.—Fig. 7, Sec. 10gg, shows a sectional view of the widely used locomotive cylinder lubricator made by the Michigan Lubricator Company, of Detroit, Michigan. The triple-feed lubricator provides a feed for each cylinder and one for the air pump.

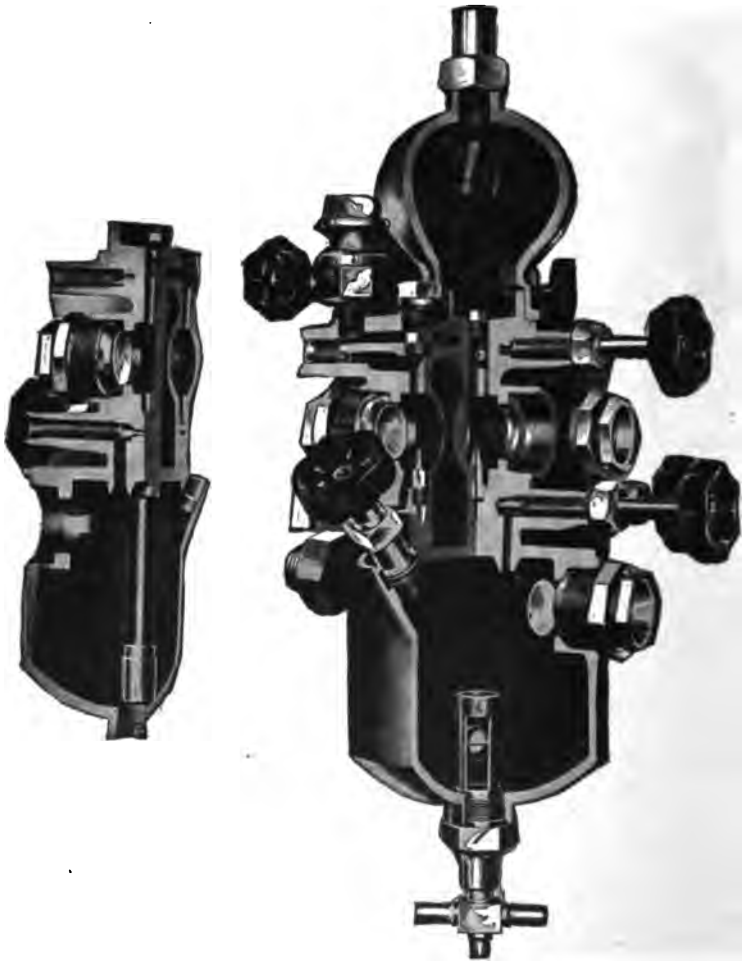

FIG. 7. SEC. 10gg.—Sectional view of the Michigan triple-feed bull's-eye locomotive lubricator.

In some types of small, simple, direct locomotives, a separate lubricator is provided for the air pump.

Locomotive lubricators are also made with four feeds, to supply two cylinders and two air pumps, or two high-pressure cylinders and two low-pressure cylinders. Five feed lubricators, for use with superheated steam, Compounded or Mallet type locomotives, provide four feeds for valve and cylinder lubrication and a fifth for the air pump.

Locomotive lubricator connections usually straddle the throttle, and "chokes" must be provided to maintain the balance of the lubricator. Sometimes these "chokes" are in the cylinder feeds, within the lubricator, or they may be in the automatic chest plugs, which have an automatic ball valve, giving a large area when the valve is opened, but reduced when the valve is closed. A "Michigan Automatic Steam Chest Plug" is shown in Fig. 8, Sec. 10gg.

Fig. 8. Sec. 10gg.—Michigan automatic steam chest plug.

When preparing the locomotive before running, the cylinders should be drained of water, through the cylinder cocks. Do not give the engine full throttle in starting, as all of the condensed steam will be carried into the steam chests and cylinders, tending to wash off the oil and cause waste.

If the lubricators feed irregularly, examine the choke plugs, for enlarged openings. If the feed of the lubricator increases, when the throttle is closed, the lubricator is out of order and should be immediately returned to the shop.

DETROIT LOCOMOTIVE LUBRICATORS.—Fig. 9, Sec. 10gg, shows a Five-Feed Standard Detroit Bullseye Locomotive Lubricator. This is for use on simple locomotives, where an individual oil feed is to be used for the lubrication of both the steam-chest valves and cylinders and one oil feed for the lubrication of the air pumps. Capacity, 5 pints.

Fig. 10, Sec. 10gg, shows a view of a Detroit Bullseye, Eight-Feed Standard Locomotive Lubricator. This is intended for lubricating the high-pressure steam-chest valves and cylinders, the low-pressure cylinders and the air pumps on compound locomotives. The two middle feeds may also be used, one for the lubricating of the air pumps and the other for delivering oil into the low-pressure receiver pipe, thus providing lubrication for the low-pressure valves.

Fig. 11, Sec. 10gg, shows a straight type, Detroit Steam Chest Plug, sectional view. It is used where the oil is delivered into the steam way, or valve chamber, in order that the lubricator may feed against a constant boiler pressure in the oil pipes, instead of a pressure fluctuating with that in the steam chest.

Fig. 12, Sec. 10gg, shows two forms of lubricator chokes of the Detroit model. These are used when the feeds are choked at the lubricator, instead of at the steam chest. The ball type of choke is adapted to all lubricators where the feeds so fitted are used for lubricating the air pump. The brass choke is used for balancing the feeds for valve and cylinder lubrication. It may also be applied to lubricators where other than air-pump feeds are to be choked.

FIG. 9. SEC. 10gg.—Detroit bull's-eye five feed standard locomotive lubricator.

OPERATION OF DETROIT LUBRICATORS (BULL'S-EYE LOCOMOTIVE TYPE).—Fig. 13, Sec. 10gg, shows a Detroit Three-Feed Standard Bull's-eye Locomotive Lubricator, used for lubricating the steam-chest valves and cylinders and one air pump on simple locomotives in average service. The parts are lettered, and the names of the parts, and method of operating are as follows:

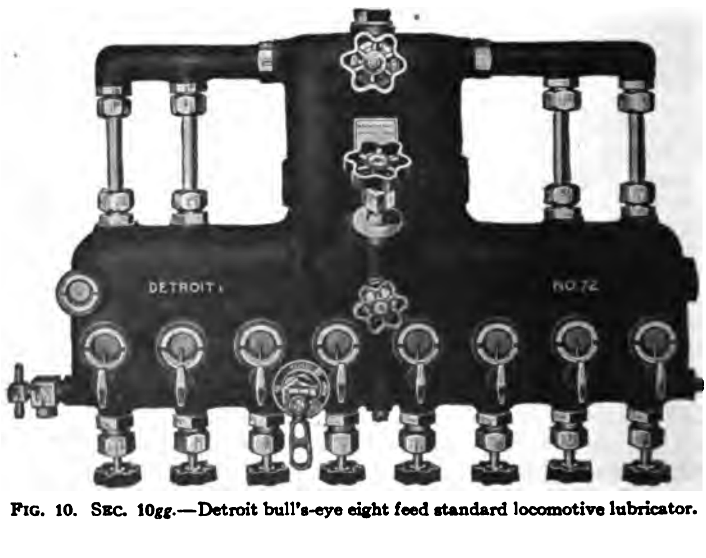

FIG. 10. SEC. 10gg.—Detroit bull's-eye eight feed standard locomotive lubricator.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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2									
3									
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To fill or refill, move the oil-control valve *C* to "closed" position, close water valve *D* and steam valve *B*. Open drain valve *G* and fill with clean strained oil. If lubricator is under pressure, proceed as before, but remove filler plug slowly, to allow pressure above the oil to escape and the air to enter. Fill the reservoir full. If there is not sufficient oil for this purpose, use water to make up the required quantity. This method will expel the air and enable the feeds to start without exhausting the water from the condenser, or materially lowering its level. The regular boiler valve must be left open at all times, and the steam valve *B*, at the top of the condenser, must be left open wide while the locomotive is in service. Start the lubricator about 15 minutes before leaving the terminal. Be sure that the regular boiler valve is open, then open wide the steam valve *B*, at the top of the condenser, and keep it wide open while the lubricator is in operation. Allow sufficient time for the condenser and sight-feed glasses to fill with water. Open the water valve *D*. Three turns will give full port opening. Open the oil-control valve *C*. In adjusting the lubricator feeds, for a class of service, after the oil valve *C* is opened, regulate the cylinder and pump feeds by means of valves *E*, *E*, *L*. After these valves have been once adjusted do not use them in the ordinary operation of the lubricator. The oil-control valve is used to throttle the feeds and to shut them partly or all the way. Adjust the feeds to the maximum number of drops required for the hardest track service, then the number of drops can be decreased for the lighter service by throttling with the oil-control valve. For short stops, use the control valve, for terminal stops close the control valve, then the water valve *D* and last the steam valve *B*.

FIG. 11. SEC. 10gg.—Straight type Detroit steam chest plug.

Ball Choke

Brass Choke

FIG. 12. SEC. 10gg.—Detroit lubrication chokes.

NOTES ON LOCOMOTIVE CYLINDER LUBRICATORS.—In cases where the locomotives pass through alkali, salt water or oil well regions, the water supply becomes impregnated with saline matter. This is carried over into the sight-feed chamber, and as the percentage of saline matter increases, it in turn increases the buoyancy of the water,

FIG. 13. SEC. 10gg.—Detroit three-feed standard bull's-eye locomotive lubricator.

which in turn exerts a greater influence on the drop of oil forming at the end of the feed nozzle. This results, that as the percentage increases, the drop becomes smaller and the rate of feed faster.

Irregular feeding may result in loss of oil. This may be due to a worn choke, a deposit at the end of the feed nozzle, or a large percentage of saline matter in the water of the sight-feed chambers.

AIR PUMPS

THE LOCOMOTIVE AIR PUMP.—When locomotives are equipped with hydrostatic lubricators, for lubricating the engine cylinders, an additional feed is supplied on the lubricator for the steam cylinder of the air pump. When a forced-feed lubricator is used for lubricating the engine cylinders, an additional pump is usually supplied for the air pump. In some cases a separate single-feed hydrostatic lubricator is furnished for the air pump. None of these plans are very satisfactory. In the case of a heavy freight, the lubricant is only fed to the steam cylinder of the air pump when the engine is in motion. This is the time when the air pump on a heavy freight requires the least amount of lubrication. When a locomotive that is equipped with forced feed makes a stop, with a heavy train, the air pump is usually required to make several hundred strokes per minute in recharging the train line, during which operation the pump often becomes so dry that its operation is seriously interfered with.

With the hydrostatic feed, the amount of oil fed to the air-pump cylinder is left in the hands of the train crew, and usually the oil is fed continuously, regardless of whether the pump is in operation or not.

It is common practice to introduce cylinder oil to the air cylinder through what is known as the oil cock, at the top of the head. This method is not generally good, however, because the oil is not generally fed to the cylinder until indications of its need are observed. Then large quantities are run in and carbonization results. Often the valves are gummed. Some engineers have the practice of allowing the oil to be poured in over the intake strainer, which tends to gum it up and causes dirt to accumulate, which interferes with efficiency and capacity of the pump.

One of the best lubricators for this purpose is provided with a feed to the steam pipe of the air pump steam cylinder, a feed to the air inlet of the air cylinder, and a feed to the top head of the air cylinder.

DRIVING-WHEEL AND TRUCK JOURNALS

DRIVING-WHEEL AND TRUCK JOURNALS.—The lubrication of locomotive driving-wheel and engine truck journals depends upon the oil fed by the sponging in the cellars of the journal boxes.

Fig. 14, Sec. 10gg, shows a typical driving-box cellar and the proper method of packing it, to prevent the ends of the waste from being drawn up between the journal and the brasses, which would result in a hot box. As shown in the figure, the packing is composed of several separate portions which are placed in position across the cellar. The packing is thus separated for two reasons, namely: (*a*) To make the operation of examining the box easy, without tearing the entire packing to pieces with the tool; and (*b*) to reduce the possibility of the waste being carried up by the journal, as described above. The tops of driving and engine truck boxes should be packed with a thin covering of cotton waste, and, if possible, a thin sheet-iron covering should be made to slide over the box. The cotton waste serves to hold the oil in the cellar and to gradually feed it to the journal. It also aids in excluding dirt and grit from the bearing.

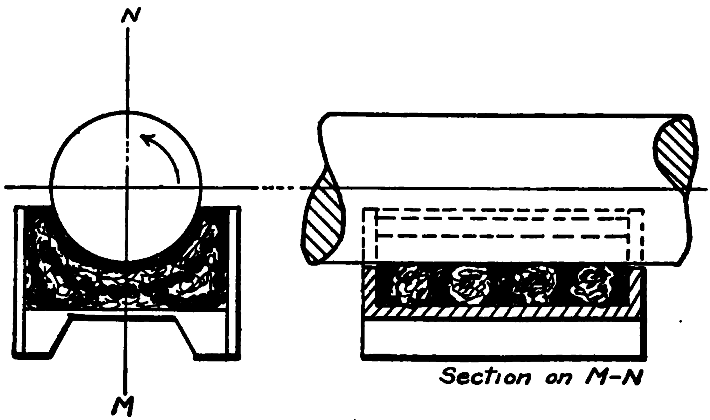


FIG. 14. SEC. 10gg.—Method of packing locomotive driving-box cellars.

At frequent intervals, the packing in driving and engine truck cellars should be carefully examined. For through passenger locomotives this examination should be made at least once every two weeks, and for local passenger and freight locomotives once every month.

Journal boxes under locomotive tenders should be oiled and packed according to the methods described for passenger and freight cars. About one thousand miles is the average run for passenger locomotive tenders. for each oiling.

Many failures of driving boxes can be traced to lack of lubrication. These failures result in the withdrawal of the locomotive from service, new crown bearings applied, the journals trued off, and sometimes new axles applied. This, together with the drop-pit work entailed, such as

removing rods, etc., suggests how important a factor in reducing the cost of locomotive upkeep lubrication of the driving boxes is.

Several investigators have found, that when a set of gauges are applied to the side of a driving box, the journal of which runs in a bath of oil, indicate that the pressure is zero at the point where the oil enters, and that it gradually increases up to a point just over the crown in the direction of the movement of the journal, from which point it rapidly diminishes. In practice, it is often observed, that the crown brasses wear upward and slightly forward.

Fig. 15, Sec. 10gg, shows the general arrangement of the cotton waste and oil wick feeders for the top of a typical driving box. It is recom-

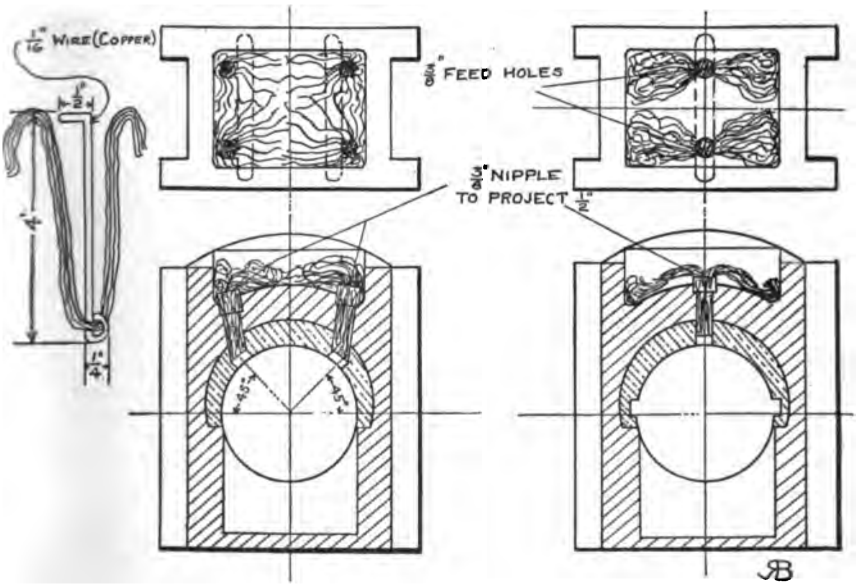


FIG. 15. SEC. 10gg.—Method of arranging wick feeders at the top of locomotive driving boxes.

mended that a piece of woolen yarn, attached at one end to a 1/16-inch copper wire, be inserted in the oil hole as shown, to act as a wick-feed for the oil. This will prevent dirt from entering and can be adjusted to regulate the feed. The wire provides an easy method of inserting and removing the wick-feeds.

NOTES.—The lubrication of "driving crown brasses" and "driving axle journals" is more important than lubrication of any other part of the locomotive. The driving axle boxes of locomotives support the weight of the boiler and its fittings, and, due to the conditions existing in locomotive practice and design, such as the gauge of the track, width of the fire-box, etc., the driving axle journals are made as short as possible. As a result they are usually made only as long, more or less, as their

diameter. This condition is not found in stationary practice, because the length of journals is not limited, and as a result it is general practice to make the bearings twice the diameter of the journal in length.

It is, therefore, evident, that with the enormous weight on the driving axle journals, of many thousands of pounds, and the high rubbing speeds of the journals of fast locomotives, combined with the reduced bearing area, and consequent increased bearing pressure per square inch, the lubricating conditions are severe.

LOCOMOTIVE PACKING TOOLS

LOCOMOTIVE PACKING TOOLS.—For caring for driving and engine truck box cellars. The curved type of tool, as shown in Fig. 16, Sec. 10gg, is intended for use when the space is restricted. The tool

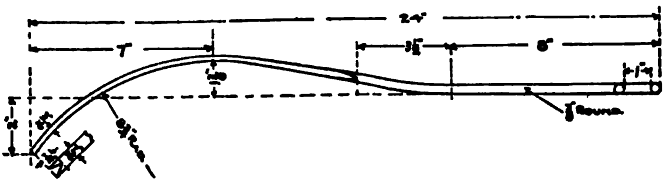


FIG. 16. SEC. 10gg.—Curved packing tool.

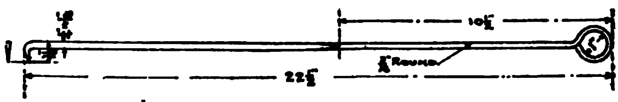


FIG. 17. SEC. 10gg.—Straight packing tool, thin blade.

shown in Fig. 17, Sec. 10gg, has a thin blade and is intended to be used for removing small pieces of waste that have been drawn up and which may be caught between the brass and axle.

RAILWAY LUBRICANTS

RAILROAD LUBRICATING OILS.—The following data were secured from a report as a result of the efforts of a special committee appointed by the Chairman of the National War Service Petroleum Committee, to represent the oil refiners of the United States, and in conjunction with a committee of the railroad chemists. The comparison of the recommendations of the refiners and the railroad chemists on the various grades of oils are as follows:*

Valve oil "A" is recommended for power plants and locomotive engines not using superheated steam. *Valve oil "B"* is for use on superheated engines:

Name	Flash, Fahr.	Viscosity, Saybolt	Fat
Valve oil "A"			
R. R. chemists	525	115–140	5–8%
Refiners	460 minim	125–145	6–8%
Valve oil "B"			
R. R. chemists	575	170–195	4–6%
Refiners	500	160–180	5–7%

Coach engine oil is recommended for use in the journal boxes of all steam and electric locomotives and passenger train cars. It is also recommended for the side bearings and for the machinery of locomotives:

* Note. The following comments on the specifications as recommended by the railroad chemists, as compared with those suggested by the refiners, were embodied in a letter to refiners and lubricant manufacturers, signed by the Director of the Oil Division of the Fuel Administration:

Valve oil "A" is recommended for power plants and locomotive engines not using superheated steam. You will notice that the refiners recommended a minimum flash of 460°, whereas the railroad chemists recommended a flash of 525°. On valve oil "B," which is to be used on superheated engines, the refiners recommended a minimum flash of 500° F., while the railroad chemists recommended 575° Fahrenheit.

If the recommendations of the railroad chemists be accepted, then it is only possible to make these oils from Pennsylvania crude, and this eliminates the manufacture of any of these oils from Mid-Continent crudes. The same thing follows on valve oil "B"; that is, none of these oils can be made from Mid-Continent crudes.

On car oils and coach engine oils, railroad chemists ask that a clause be added: "The purchaser may further ask for heavy, intermediate or light summer oils, and divide them into these different classes, according to gravity." We feel that there should be no reference to gravity in the specifications, as gravity has nothing to do with the quality of an oil, and gravity only indicates from what crude it is manufactured.

Name	Flash, Fahr.	Viscosity, Saybolt, at 210° Fahr.	Viscosity, Saybolt, at 100° Fahr.
R. R. chemists, summer......	325	60–75	....
R. R. chemists, winter........	250	50–65	....
Refiners "A"...............	300	.....	450–500
Refiners "B"...............	225	.....	200–250

Car oil is recommended for use for journal-box lubrication of all freight and work cars. It may be used for the lubrication of side bearings and journal boxes of locomotives, tenders, and passenger train cars, and for the machinery of locomotives:

Name	Flash, Fahr.	Viscosity, Saybolt, at 210° Fahr.	Viscosity, Saybolt, at 130° Fahr.
R. R. chemists, summer......	300	50–60	....
Refiners, heavy..............	300	.....	275–300
Refiners, summer............	275	.....	175–200
R. R. chemists, winter........	225	45–55	....
Refiners, winter..............	225	.....	80–100

SPECIFICATIONS.—The following tentative specifications for various grades of lubricants for railroad use, as proposed by the railroad chemists' committee, the tests to be in accordance with the United States Railroad Administration standard code for testing, are as follows:

COACH ENGINE OIL

1. Scope. The oil is intended to be used for the journal-box lubrication of all steam and electric locomotives and passenger train cars. It is also intended for use on side bearings and for the machinery of locomotives.

2. Two classes of oil, known as summer coach engine oil and winter coach oil, respectively, may be purchased. The purchaser shall in all cases state which class is desired.

3. Coach engine oil will be purchased on approved samples submitted by manufacturers to the authorized agents of transportation companies.

4. Samples submitted for approval must comply with the following detailed requirements:

(*a*) *Gravity.* The gravity of the oil shall not be under 18° Baumé and not over 30° Baumé. The purchaser may further ask for heavy, intermediate or light summer or winter coach engine oil, in which case the gravity of the heavy grade shall be not under 18° Baumé and not over 20° Baumé, the intermediate grade shall be not under 22° Baumé and not over 26° Baumé, and the light grade not under 26° Baumé and not over 30° Baumé.

(*b*) *Impurities.* The oil shall not contain more than 0.25 per cent. of total impurities, including water.

(*c*) *Cold Test.* The cold test of summer coach engine oil shall not be higher than 32° Fahrenheit, and of the winter grade not higher than zero° Fahrenheit, unless otherwise specified by the purchaser.

(*d*) *Flash Test.* The flashing point of summer coach engine oil shall not be lower than 325° Fahrenheit, and of winter coach engine oil not lower than 250° Fahrenheit, when tested in the Cleveland open cup.

(*e*) *Viscosity.* The viscosity of summer coach engine oil at 210° Fahrenheit shall not be under 60 and not over 75 seconds, and of winter coach engine oil not under 50 and not over 65 seconds when tested by means of the Saybolt Universal Viscosimeter.

(*f*) *Tarry Matter.* Coach engine oil shall not yield over 0.1 per cent. of chloroform soluble, tarry precipitate by weight. In routine tests the purchaser will have the option of accepting shipments which do not show precipitation in one hour.

(*g*) *Acid Test.* The oil shall be neutral, not showing the presence of free acid or alkali when shaken with neutral water, using methyl orange and phenolphthalein as indicators.

(*h*) All of the tests detailed in this section shall be made in accordance with the U. S. R. A. Standard Code for Testing Lubricating Oils.

5. The manufacturer may furnish pure mineral oil or a combination thereof with non-drying fatty oils and lead soap.

6. Samples of oils meeting the above tests will be placed on the purchasers' approved list.

7. When a sample has been approved, purchases may be made in accordance therewith The corresponding product of any manufacturer of oil which does not produce satisfactory performance in service may at any time be removed from the approved list.

8. Purchasers may take samples of shipments of oil purchased on an approved sample, in which case each sample will represent the contents of a tank, a carload or fraction thereof. If tests on this sample do not agree with those obtained on the approved sample, such shipments may be rejected.

CAR OIL

1. Scope. This oil is intended to be used for journal-box lubrication of all freight trains and work cars. It may be used for the lubrication of side bearings and journal boxes of locomotives, tenders and passenger train cars, and for the machinery of locomotives.

2. Two classes of oil, known as summer car oil and winter car oil, respectively, may be purchased. The purchaser shall in all cases state which class is desired.

3. Car oil will be purchased on approved samples submitted by manufacturers to the authorized agents of transportation companies.

(*a*) *Gravity.* The gravity of the oil shall not be under 19° Baumé and not over 31° Baumé. The purchaser may further ask for heavy, intermediate or light summer or winter car oil, in which case the gravity of the heavy oil shall not be under 19° Baumé and not over 23° Baumé, the intermediate oil not under 23° Baumé and not over 27° Baumé, and the light oil not under 27° Baumé and not over 31° Baumé.

(*b*) *Impurities.* The oil shall not contain more than 0.25 per cent. of total impurities, including water.

(*c*) *Cold Test.* The cold test of summer car oil shall not be higher than 32° Fahrenheit, and of winter car oil not higher than zero° Fahrenheit, unless otherwise specified by the purchaser.

(*d*) *Flash Test.* The flashing point of summer car oil shall not be lower than 300° Fahrenheit, and of winter car oil not lower than 225° Fahrenheit when tested in the Cleveland Open Cup.

(*e*) *Viscosity.* The viscosity of summer car oil at 210° Fahrenheit shall not be under 50 and not over 60 seconds, and of winter car oil shall not be under 45 and not over 55 seconds when tested by means of the Saybolt Universal Viscosimeter.

(*f*) *Tarry Matter.* Car oil shall not yield over 0.1 per cent. of chloroform soluble, tarry precipitate by weight. In routine tests the purchaser will have the option of accepting shipments which do not show precipitation in one hour.

(*g*) *Acid Test.* Oil shall be neutral, not showing the presence of free acid or alkali when shaken with neutral water, using methyl orange and phenolphthalein as indicators.

(*h*) All of the tests detailed in this section shall be made in accordance with the U. S. R. A. Standard Code for Testing Lubricating Oils.

4. The manufacturer may furnish pure mineral oil or a combination thereof with non-drying fatty oils and lead soap.

VALVE OIL FOR POWER PLANTS

1. Scope. This oil is intended for use in the valves and cylinders of all stationary power plants using saturated or superheated steam. Locomotive valve oils of Class A may also be used for this purpose.

2. It will be purchased on approved samples submitted by manufacturers to the authorized agents of the purchaser.

3 Samples submitted for approval shall comply with the following detailed requirements:

(*a*) *Color.* The color of the oil shall be olive green. Shipments having a brown or blue cast or which are black may be rejected.

(*b*) This oil shall be free from water and all other foreign substances.

(*c*) *Fatty Oil.* The percentage of fatty oil shall be between 5 and 7. The fatty oil used may be neatsfoot oil, acidless tallow oil or prime lard oil, or mixtures of these. The presence of other fatty oils may cause rejection.

(*d*) *Acidity.* The total acidity shall not exceed 0.4 per cent., calculated to oleic equivalent.

(*e*) *Tarry Matter.* The test for tarry matter may be made on the original oil, or on oil which has been heated to determine its flashing point, or on both. The maximum amount of chloroform soluble tarry matter by either test shall not exceed 0.1 per cent. by weight. In routine test the purchaser will have the option of accepting shipments which do not show precipitation in one hour.

(*f*) *Flashing Point.* The flashing point shall not be under 460° Fahrenheit when tested in the Cleveland Open Cup.

(*g*) *Viscosity.* The viscosity at 210° Fahrenheit shall not be under 115 and not over 140 seconds when tested by means of the Saybolt Universal Viscosimeter.

VALVE OIL FOR LOCOMOTIVES

1. Scope. Two classes of oil may be purchased for this purpose, described as valve oil " A " and valve oil " B." The " A " class is intended for valves and cylinders of locomotives using either saturated or super-

heated steam; also for stoker engines and the steam and air ends of locomotive air valves, and shall be supplied by manufacturers in all cases where class "B" oil is not specifically ordered. Valve oil "B" may be purchased for the lubrication of valves and cylinders and corresponding accessories of locomotives using superheated steam.

2. *Valve oil* will be purchased on approved samples submitted by manufacturers to the authorized agents of transportation companies.

3. Samples submitted for approval shall comply with the following detailed requirements:

(*a*) *Color.* The color of the oil should be olive green. Shipments having a brown or blue cast or which are black may be rejected.

(*b*) Both classes of valve oil shall be free from water and all other foreign substances.

(*c*) *Fatty Oil.* The percentage of fatty oil shall be as follows:

Class "A"	5–8
Class "B"	4–6

The fatty oil used may be neatsfoot oil, acidless tallow oil or prime lard oil, or mixtures of these. The presence of other fatty oils may cause rejection.

(*d*) *Acidity.* The total acidity of valve oil "A" shall not exceed 0.4 per cent., and of valve oil "B" not over 0.3 per cent. when calculated to oleic acid equivalent.

(*e*) *Tarry Matter.* The test for tarry matter may be made on the original oil, or on oil which has been heated to determine its flashing point, or on both. The maximum amount of chloroform soluble tarry matter by either test shall not exceed 0.1 per cent. by weight. In routine test the purchaser will have the option of accepting shipments which do not show precipitation in one hour.

(*f*) *Flashing Point.* The flashing point of valve oil "A" shall not be under 525° Fahr., and of valve oil "B" not under 575° Fahr. when tested in the Cleveland Open Cup.

(*g*) *Viscosity.* The viscosity of valve oil "A" at 210° Fahr. shall not be under 115 and not over 140 seconds, and of valve oil "B" not under 170 and not over 195 seconds when tested by means of the Saybolt Universal Viscosimeter.

SPECIAL CAR OIL.—For a waste-packed journal, a black oil of about 50 to 75 Viscosity at 212° F., to which is added a small amount of red lead, graphite or other finely divided material, which will leave a coating between the wearing surfaces when motion is stopped for a considerable time, as in the case of a car on a siding, is often used.

COST OF LUBRICATION.—The results obtained on one large railroad were as follows:

Locomotive mileage per quart cylinder oil	122 miles
Locomotive mileage per quart engine oil	50 miles
Locomotive mileage per pound of waste	1 mile

RAILWAY LUBRICATION—GREASE.—It has been found in practice, that for trains subject to frequent stops and starts, grease lubrication will give an average of lower total frictional resistance, for the

following reasons: Greases resist being squeezed out from between the bearing surfaces, but can be forced into the bearings at high speeds. While they offer greater frictional resistance at high speeds than oil does, nevertheless at low speeds and for starting, the thicker film present with grease lubrication reduces the frictional resistance, due to the greater separation of the bearing surfaces, and there is consequent reduced tendency for the surfaces to interlock.

Particularly good results are obtained in the lubrication with grease of driving axles and locomotive pins. The lubrication is more automatic and fewer hot boxes occur, when grease is used, than when oil is used.

TRACK GREASE.—A satisfactory lubricant for track grease has been made as follows:

26.4 per cent. Illinois steam-refined cylinder stock.
26.4 per cent. 34° bottoms.
24.3 per cent. resin oil.
22.0 per cent. water.
0.9 per cent. pine tar.

AIR BRAKE

The railroad air brake is a combination of operating parts, controlled and operated by compressed air. The purpose of the air brake is to provide an effective and quick method for braking a train or car. The process consists in using a mechanism operated by compressed air, by means of which brake shoes are forced against the wheels, so that the friction between the shoes and the wheels retards the rotation.

The air-brake equipment consists essentially of:

1. An "air compressor," to furnish the compressed air.

2. An operating valve, called the "brake valve," used by the engineer to operate the brakes.

3. A "brake pipe," which provides a means of connection between the brake valve and the brake apparatus for each moving component in the train. The brake pipe is connected between the different cars by means of a flexible hose, and the end of the train is closed.

4. A "brake cylinder," which is used to transform the expansive power of the compressed air into mechanical force on each car.

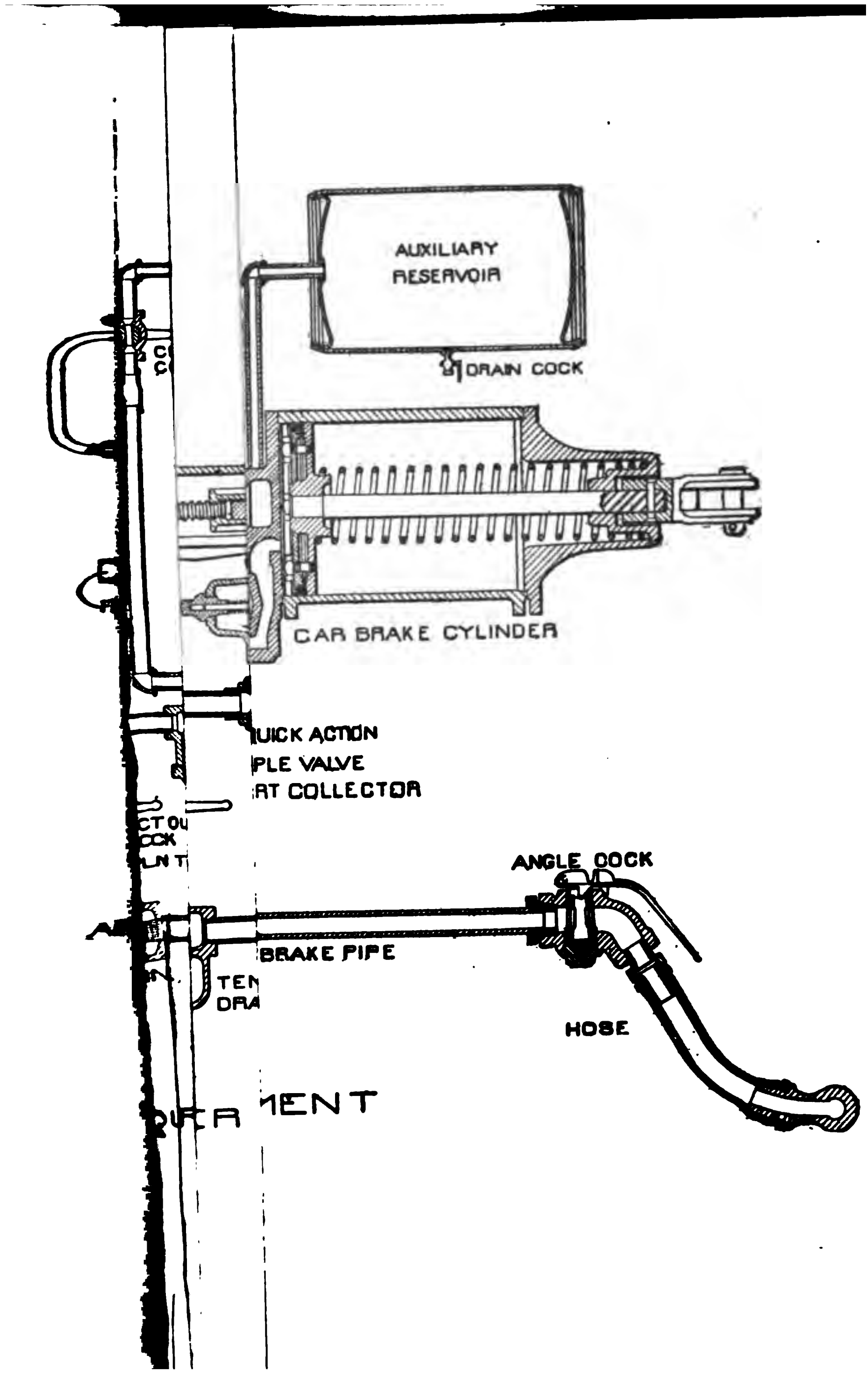
5. A "foundation brake gear," which is a combination of rods and levers for transmitting the mechanical force from the brake cylinders to the brake shoes, which apply this, in the form of retarding force to the wheels.

6. "Brake shoes." The brake shoes are the means for applying the retarding force to the wheels.

7. The parts numbered 1 to 6, as above, include those parts which are essential to obtain the desired effect. However, in practical operation, other additional devices for improving the operation of the equipment, such as storage reservoirs, for air; feed valves, compressor governors, air gauges, etc., are provided.

PLAIN AUTOMATIC AIR BRAKE.—The automatic air brake is designed so that the brake will be automatically operated in case an accident should occur, which would permit the air to escape to the system.

With the automatic system, each car is equipped with an auxiliary reservoir, which carries a supply of compressed air, sufficient to operate the brakes for that particular car, and a triple valve, which has connected to it the brake cylinder, the auxiliary reservoir, and the brake pipe. The triple valve controls the air movement from the brake pipe to the car reservoir, while it is charging; from the auxiliary reservoir, to the brake cylinder, when the brakes are being applied; and from the brake cylinder to the atmosphere, when the brakes are releasing. The reservoirs, in the train, are maintained at a fixed ordinary pressure, when the brakes are not being used, and the brake is applied by reducing the air pressure in the air pipe to a point lower than the normal pressure maintained in the auxiliary reservoir. This lowering in the brake-pipe pressure is accomplished by the engineer opening the brake pipe and connections to the outside air, by means of the brake valve; or, in the case of a burst hose or accident, the brake-pipe pressure would also be lowered, thus unbalancing the pressure between the brake pipe and the auxiliary reservoir, causing the triple valve, on each car, to operate, thus applying the brakes, by admitting the air from the auxiliary reservoir to the brake cylinder, where it pushes out the brake-cylinder piston, and thus exerts



AUXILIARY RESERVOIR
DRAIN COCK
CAR BRAKE CYLINDER
UICK ACTION
PLE VALVE
RT COLLECTOR
ANGLE COCK
BRAKE PIPE
HOSE
MENT

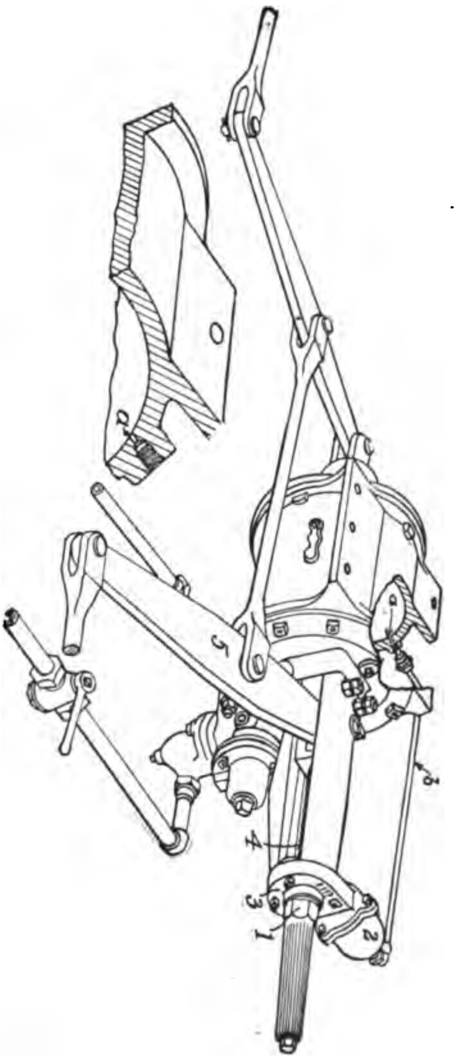


Fig. 19. Sec. 10gg.—A passenger brake cylinder with automatic slack adjuster showing lever connections.

a braking force, through the rods and levers of the brake gear, which press the brake shoes against the wheels. When the brake is to be released, compressed air is admitted to the brake pipe from the main reservoir, carried by the locomotive, through the brake valve, bringing the pressure in the brake pipe above the pressure existing in the auxiliary reservoir, thus causing the triple valve to return to its original position, and opening connections from the brake pipe, to recharge the auxiliary

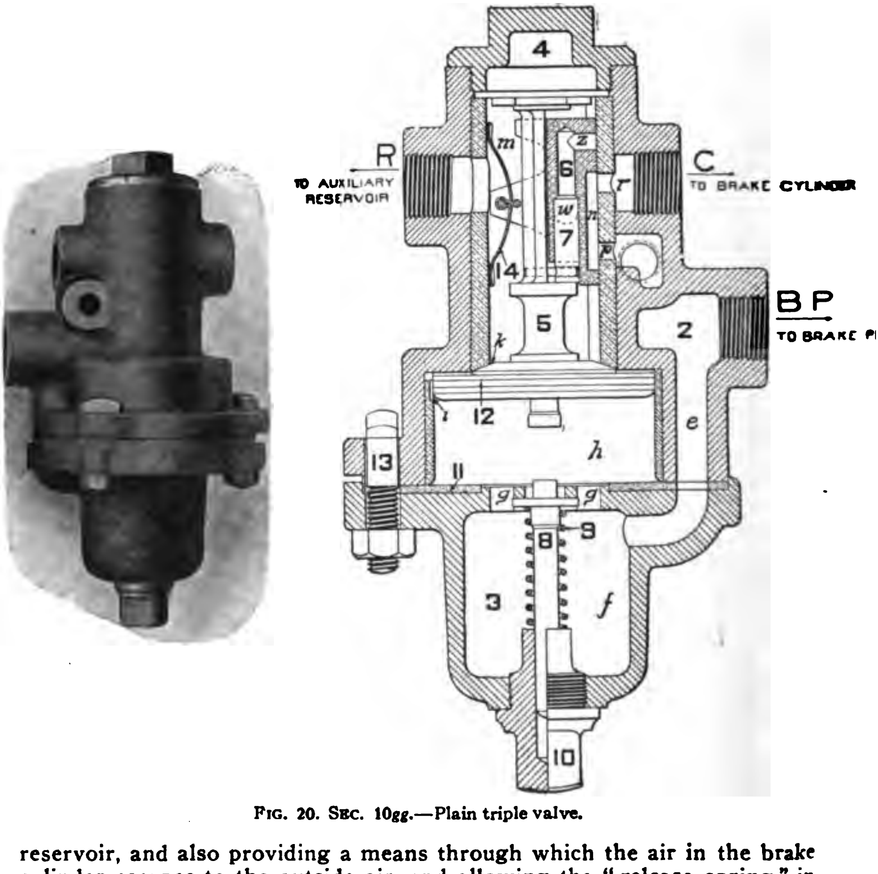


FIG. 20. SEC. 10gg.—Plain triple valve.

reservoir, and also providing a means through which the air in the brake cylinder escapes to the outside air, and allowing the "release spring," in the brake cylinder, to return the piston to its original position, and to release the brake shoes from the wheels, through the action transmitted by the rods and levers.

Two general types of air compressors are used—the simple and the cross-compound.

Fig. 18, Sec. 10gg, shows a Westinghouse quick-action automatic brake equipment, for passenger service.

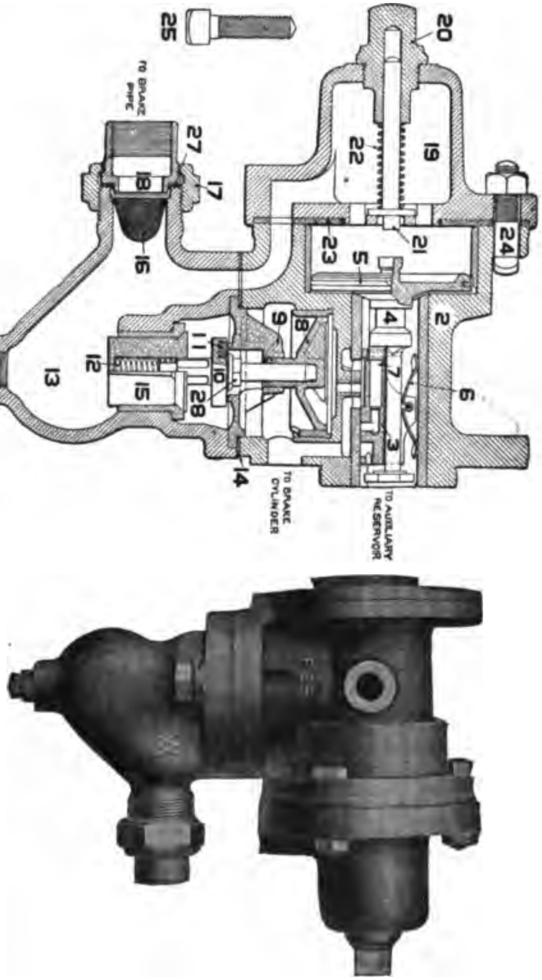


FIG. 21. SEC. 10gg.—Quick action triple valve.

Fig. 19, Sec. 10gg, shows a passenger brake cylinder (Westinghouse), with automatic slack adjuster, showing lever connections.

Fig. 20, Sec. 10gg, shows a plain triple valve, and Fig. 21, Sec. 10gg, shows a quick-action triple valve.

LUBRICATING THE TRIPLE VALVE AND BRAKE CYLINDER.—In lubricating and cleaning the triple valve, it should be taken apart, and the internal metal parts immersed in benzine or gasoline. The cylinders should then be cleaned in oil. In general, the triple valve should be cleaned and lubricated about once a year, but the interval is determined in each particular case by working conditions, inspection, etc. Conditions exposing the triple valve to extremes of weather, dust, dirt, etc., involve frequent inspections and lubrication. All oil, gum or grease should be thoroughly removed from the slide valve and seat, in the bushing (slide valve is shown in Fig. 22, Sec. 10gg. as No. 6). The face of the graduating valve, the surfaces of the slide valve, the slide-valve seat, and the upper portion of the bushing should be lubricated with very fine, dry graphite. This should be rubbed in, so that it will adhere and fill the pores of the brass, and leave a light coat of graphite. A method to apply the graphite is to use a stick, having a small piece of chamois fixed at one end. The chamois is dipped into the dry graphite, and rubbed onto the surfaces as specified, and after rubbing, the slide valve is struck a light blow with a stick, so that the excess graphite will be knocked off. Care should be taken when handling the parts after lubricating with graphite, so that the hands do not come into contact with the lubricated parts and remove the graphite.

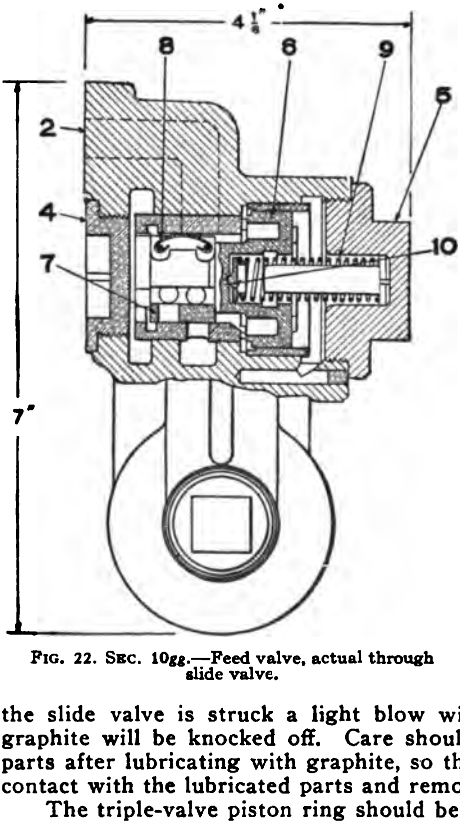


FIG. 22. SEC. 10gg.—Feed valve, actual through slide valve.

The triple-valve piston ring should be lubricated by first pushing the piston to a released position and applying a couple of drops of oil to the piston bushing. There should be no free oil left on the parts, and no oil should be allowed to get onto the gaskets or rubber-seat valves.

For lubricating the brake cylinders, the branch pipe cut-out cock should be closed and the auxiliary reservoir drained. The piston sleeves and non-pressure head should be fastened together with a nail, which can be inserted through a hole provided in the sleeve, or a suitable clamp may

be used. The nuts from the non-pressure head may be removed, and the piston taken from the cylinder. The residue of old lubricant should then be removed with the aid of kerosene, which, afterward should be completely removed from the cylinder, in order to prevent damage to piston and the packing leather. Any rust on the cylinder walls should be removed with sandpaper. The old lubricant should be removed from the expander rings, the leather should be carefully examined, and replaeed if not in good condition. A thin coating of brake-cylinder lubricant should then be applied to the cylinder with a brush. A semi-fluid graphited lubricant, of about one-half the consistency of commercial vaseline, will make a satisfactory lubricant for this purpose.

AIR-BRAKE LUBRICATION.—Mr. R. E. Miller, Chief Engineer of Tests, Westinghouse Airbrake Co., states: The only correct lubrication for the triple valve is powdered graphite, as oil or any oil product has a tendency to create a vacuum under the valve seat, which causes the brake to operate on the emergency ports, due to the sudden freeing of the valve.

AIR-BRAKE LUBRICANTS.—The Westinghouse Company has found that lubricants containing animal oils cause an electro-chemical action on the brass piston rings.

An air-brake lubricant is subjected to temperatures of the air, ranging from 30° Fahr. below zero to 100° Fahr. above. The lubricant should, therefore, have a low cold test. There is some moisture to be met with in some climates or during rainy weather. There is a strong compression in the brake cylinders, and packing leathers are used. The lubricant must have no deteriorating effect upon the leathers, and must keep them pliable. The lubricant used must have no tendency to ball up or leave a residue in the bottom of the cylinders.

FLANGE OILING

FLANGE OILERS.—The purpose of flange oilers for use on locomotives is to reduce flange wear, and thus increase tire mileage, reduce rail wear, protect frogs and switches, and reduce shop work.

The Detroit Lubricator Company gives the following figures illustrating the advantages of flange oilers: Taking the average of a number of engines in service, passenger locomotives of the Pacific type on one railroad showed 16,500 miles (tire mileage) without flange oilers, and an

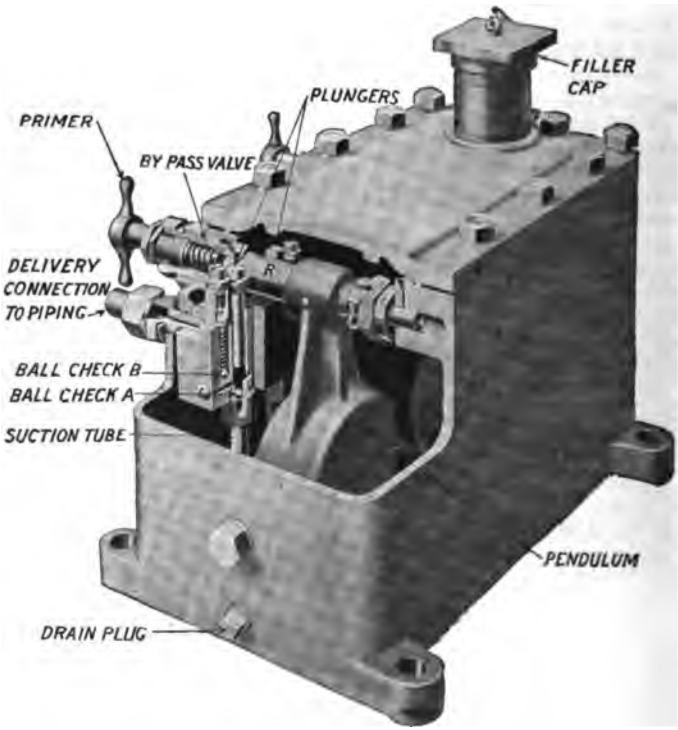


FIG. 23. SEC. 10gg.—Detriot automatic flange oiler.

increase to 39,700 miles after the application of flange oilers. On another road, engines of this type showed 39,700 miles without flange oilers, with an increase to 91,800 miles with flange oilers; while a ten-wheel passenger engine increased mileage from 25,000 to 84,000 miles. The average of ten Consolidation type locomotives in freight service before application of flange oilers was 23,000 miles. Flange lubrication on the same engines increased this mileage to 46,100 miles between tire turnings. * * * The average loss of metal, on account of flange wear, results in the necessity of taking 3/4-inch of clear stock from the tread, in order to form new

flanges. For eight driving wheels there are six inches of solid metal reduced to scrap. * * * By reducing friction between tire and rail, to prevent excessive flange wear, it is evident that there will be a like reduction in wear, resulting from this action in the cutting of the rail, and this is particularly true on curves. Taking the average of curves greater than five degrees, it has been found that the life of the outside rail has been increased from 12 to 32 months with lubrication, while the inside rail shows an increase from 13 to 33 months.

Fig. 23, Sec. 10gg, shows a Detroit four-feed flange oiler, as manufactured by the Detroit Lubricator Co. In this lubricator the oil is forced under pressure to the point of lubrication by means of two plungers,

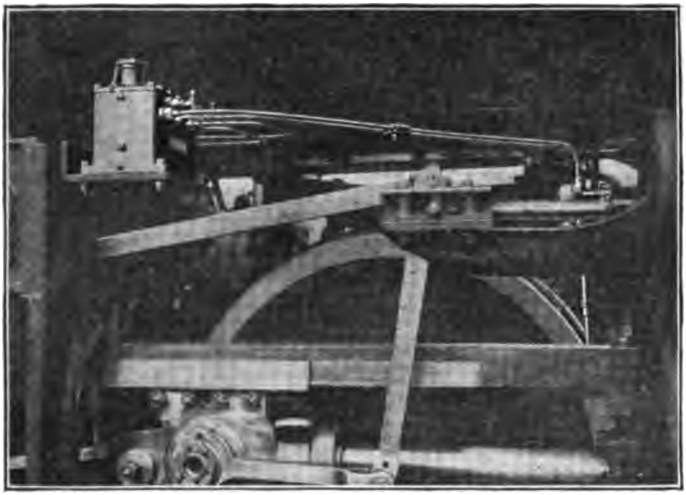


FIG. 24. SEC. 10gg.—Installation of 4-feed Detroit automatic flange oiler on Santa Fé type locomotive showing piping of feeders in forward pair of drivers.

actuated by a swinging pendulum. This pendulum receives its motion from the swaying of the locomotive. The oil thus forced is pumped into the pipe line and to the regulating valve, which is installed immediately above and adjacent to the feed nozzle, which supplies the oil to the flange. On straight track there is just enough oil fed to the flange to prevent cutting of the flange. On approaching a curve, depending upon the degree of the curve and the speed of the train, the lateral motion and the swaying of the locomotive increases the swing of the pendulum, and thereby increases the amount of oil delivered.

The operation of the oiler is as follows, referring to Fig. 23, Sec. 10gg: The swaying of the locomotive causes the pendulum to swing. It is pinned to the rocker shaft R, through which a rocker arm passes and engages with the plungers. On the upstroke of a plunger, the oil is drawn up past the ball check A; on the downstroke the ball check A closes

the passage into the suction tube, and the oil is forced past the ball check *B*, into the pipe and to the feed nozzle.

Fig. 24, Sec. 10gg, and Fig. 25, Sec. 10gg, show the oiler installed.

Various oils are used with this oiler—thin crude oil, fuel oil, or a

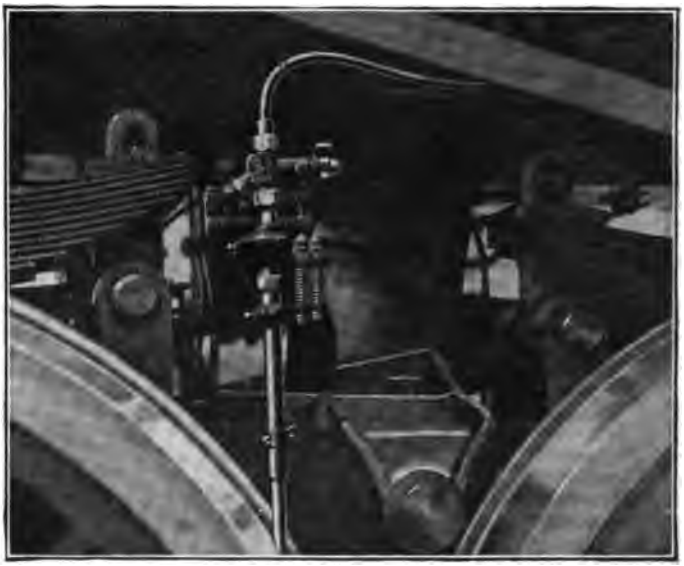


Fig. 25. Sec. 10gg.—Showing detail of regulating valve and feed nozzle of Detroit automatic flange oiler for application of oil to intermediate driver on Santa Fé type locomotive.

winter car oil. The following product has been successfully used for supplying these oilers:

A mixture of 50 per cent. Maltha and 50 per cent. Road Oil, testing as follows:

Grav.: 17.6.
Flash: 305.
Vis.: 160 Say. at 212° F.
Cold test: 10° F.

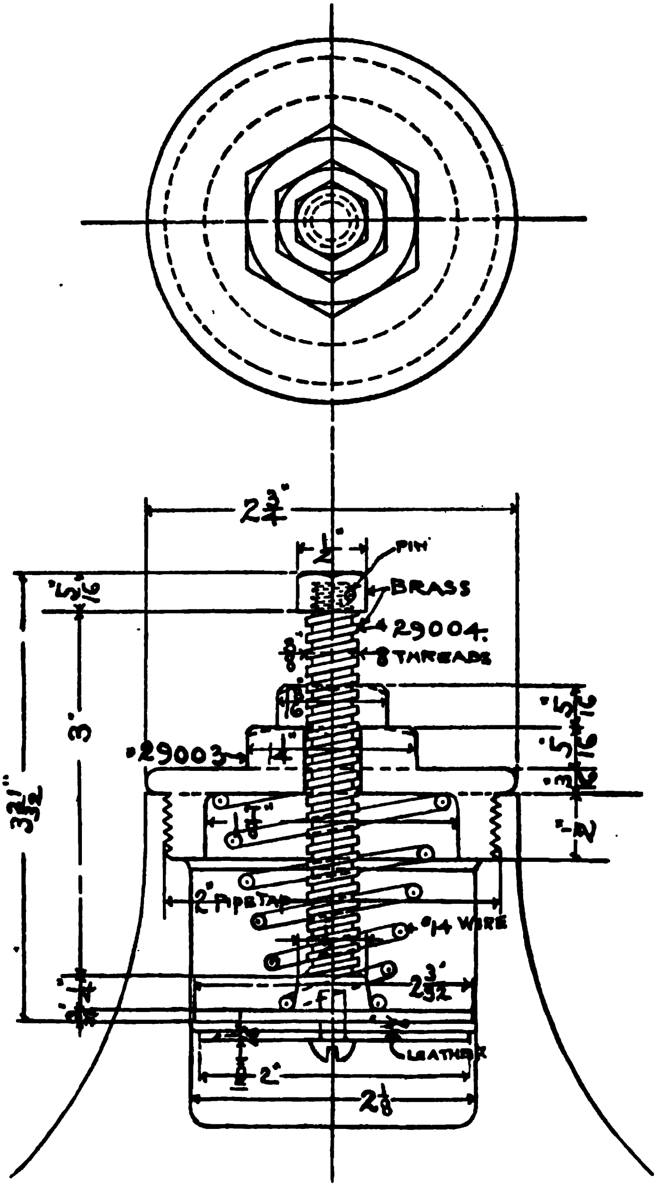


Fig. 26. Sec. 10gg.—A form of locomotive grease cup.

LIGHTING DYNAMOS

LUBRICATION OF CAR-LIGHTING DYNAMOS.—Some of the companies making lighting systems for use on railway coaches are: The Safety Car Heating and Lighting Co., the Gould Coupler Co., the United States Car Lighting Co., and the Stone Franklin Co.

With the Gould Coupler system, which is in common use, the dynamo, which is carried under the car, is belted to the car axle on the ratio of one to two. The generator is a plain, shunt-wound machine. Ball bearings of the annular type are used, and are of fairly good size. There is a ball bearing for both the pulley end and for the commutator end. These two bearings are the only points that require lubrication. When the machine is set up, the bearings are packed with a No. 2 grease, and are lubricated once every six months. They are given a charge at that time from a grease gun. The manufacturers recommend that the bearings be lubricated for every 30,000 miles of travel. The temperature conditions to which these bearings are subjected, which require that the packing of grease does not run out of the bearing, due to excessive thinning from the heat of summer and the warmth of the commutator, also require that the grease give service in winter. The grease must permit the free movement of the balls and be easy to put into the bearings when the temperature is below freezing, as in the winter.

The Safety Car Lighting Co. system differs from the Gould machine chiefly in the method of reversing the polarity of the machine when the direction of the car is reversed. With the Gould type, a special double-pole, double-throw switch is interposed between the brush leads and the external leads of the machine. This switch is operated by a weight, mounted on the shaft, and by projecting lugs on the switch blade. There is no lubrication required for the switch mechanism.

With the Safety type, the direction of the current is kept constant, by means of rotating brushes, which revolve through an angle of 90° whenever the direction of the rotation of the armature is changed. The brushes are carried on a "brush rocker," which is mounted upon two ball bearings, to give it great freedom of rotation, and also due to the fact that when the brushes have been shifted to the position indicated by the stop, the brush holder ceases to revolve and the ball bearings are expected to allow the shaft to revolve, within the brush holder, with the minimum amount of wear and tear. There are two other ball bearings on the machine, one for supporting the shaft at the pulley end and one for the commutator end.

These bearings are lubricated about once every six months. The process of lubrication is to remove both the head and bearings; that is, the pole changer and armature. The bearings are then washed, drained, and wrapped in clean cheesecloth until ready for replacement. The commutator-end grease cup should be packed with grease, in the grease-ring pocket, up to the surface of the ring. The felt washers should be examined to detect signs of hardening and glazing, which, if present, should result in replacement. A No. 2 lime-soap base grease is recommended.

In figuring speeds of the armature, the diameter of the car wheels is generally taken as 36 inches.

The grease which is used in the Gould machine is fed through a pipe

nipple, equipped with a cap and located on the side of the pulley-end housing and commutator housing, while on the Safety machine there is usually a small plugged hole provided for lubricating grease-gun purposes, one plug being on each end of the housing.

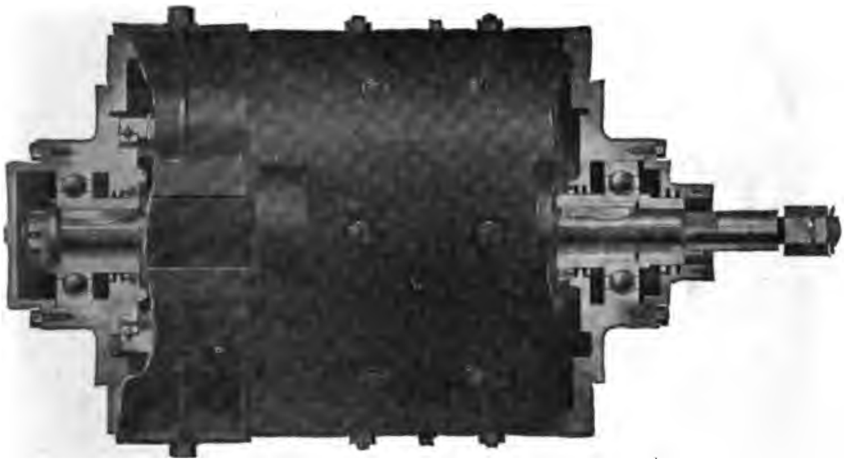


FIG. 27. SEC. 10gg.—Sectional view Safety Truck Suspended Dynamo, showing bearings. (Safety Car Heating & Lighting Co.)

FIG. 28. SEC. 10gg.—Commutator end grease cap, with grease, Safety Truck dynamo.

FIG. 29. SEC. 10gg.—Pully end grease cap, with grease packed for Safety Truck dynamo.

Fig. 27, Sec. 10gg, shows a sectional view of a Safety Truck Suspended dynamo. Fig. 28, Sec. 10gg, and Fig. 29, Sec. 10gg, show the methods of packing the pulley and commutator-end grease cups with grease.

THE STORAGE OF RAILROAD OILS

CAR STORAGE.—Fig. 30, Sec. 10gg, shows a modern equipped oil car for supplying oil at various parts of the system of a large railroad.

This car is equipped with tanks and measuring pumps and placed in charge of an efficient, careful man, who keeps records of oils issued and oils on hand, similar to those records kept by the main oil-house.

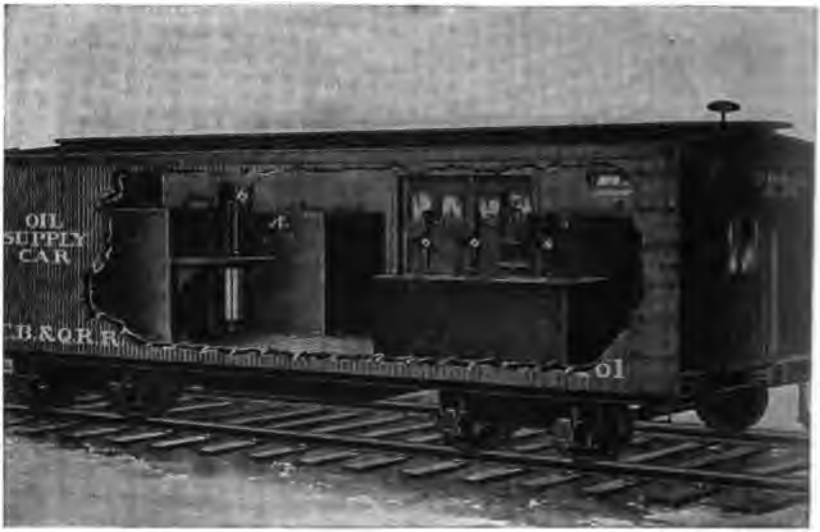


Fig. 30. Sec. 10gg.—Railroad oil supply car.

The car was designed for the Chicago, Burlington and Quincy Railroad.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

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(OVER)

FORM 1 HB

SPECIFICATIONS

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SECTION 10hh
REFRIGERATION

REFRIGERATING AND ICE-MAKING MACHINERY

REFRIGERATION.—A refrigerating machine is a heat engine reversed. There are two systems of refrigeration in general use; namely, the Absorption System and the Compression System. The system most generally met with and furnishing a field for lubrication is the Compression System.

COMPRESSION SYSTEM DESCRIBED.—In the Compression System, anhydrous ammonia gas is compressed in a compressor, to a high pressure, about 130 to 200 pounds per square inch. During the compression the temperature of the gas becomes quite high, about 200° Fahr. This hot gas is cooled by passing it through a condenser containing cooling water, and is relieved of most of its "heat of compression." The gas is then run into expansion coils, which are surrounded by brine. Here the gas is expanded from its high pressure down to about 10 pounds, and in so doing it reverses the compression conditions and absorbs heat to make up for the heat given up to the condenser, causing the brine surrounding the coils to become cold and producing a refrigerating effect. The brine is run out to the freezing room in pipes, which surround the "freezing cans" in which the ice is made.* In the "can system" 300 pounds of ice, approximately, is made in each can and the freezing requires 40 to 48 hours.

VACUUM SYSTEM.—This system uses water as the refrigerating medium and is a type of the absorption method. The water that is to be frozen is put into a container, which is connected to a vacuum pump, which is used to lower the pressure above the water to a point which is below the vapor pressure. Then the water begins to boil, and takes its heat of vaporization from the water itself, and thus lowers its temperature. The vapor then rises to an absorber, where strong sulphuric acid gives a rapid absorption. The only part of this system that requires lubrication is the vacuum pump. For the cylinder of this pump use an oil as follows: Vis. Say. at 100° Fahr., 145–160 (P. B.), or Vis. Say. at 100° Fahr., 150–165 (A. B.).

ALLEN DENSE-AIR MACHINE.—There are very low temperatures met with in this machine. Air is compressed to about 250–300 pounds per square inch, while the cylinder is water cooled, to carry off the heat of compression. Then the compressed air is taken to a cooler, where it is cooled as much as possible with water, after which it is passed into an air expander. This is a cylinder on the same shaft as the compressor cylinder. The temperature of the air drops in this cylinder to a point as low as minus 60° Fahr. The lubrication of this cylinder, due to this low temperature, is very difficult. A special cold-test oil should be used, having the lowest possible congealing point. From the expander

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* See page 861 for description of can system and other systems.

cylinder the air is passed into the refrigerating coils. These coils should be frequently blown out, to prevent clogging. As little oil should be used as possible. The following oil is recommended:

Vis. Say. at 100° Fahr.: 105–110 (A. B.).
Cold test: 0° Fahr. or better.
Flash: 300° Fahr. plus.

CARBON DIOXIDE MACHINE.—The lubricating conditions in this machine are very much the same as in the ammonia machine. However, the working pressure is higher (from 900 to 1000 pounds). The compressor cylinder temperatures are a little higher than those of the ammonia machines. As long as the water cooling is efficient and intercoolers are provided, there are no special difficulties.

OIL EXTRACTOR, AND EFFECT ON OIL VISCOSITY.—The location of the oil extractor, between the compressor and the condenser, and the efficiency of the extractor, have a direct effect upon the required viscosity of the oil which is used to lubricate the compressor cylinder.

When the oil extractor is located close to the compressor cylinder, a higher viscosity oil may be used for cylinder lubrication than is the case if the extractor is located at some distance from the compressor cylinder. This is due to the fact, that the high-viscosity oils have less tendency to vaporize and be carried over with the ammonia vapor than have the low-viscosity oils, and where the extractor is at some distance from the cylinder, there is more time for the oil vapors to condense out of the ammonia gas. This refers to oils from the same type of crudes.

COMPRESSOR CYLINDERS AND METHODS OF LUBRICATION.—Cylinders of Remington, Brunswick and Brecht machines are lubricated by the splash system, the oil being carried in the crank-case. The Remington and Brunswick machines are single acting, with one end of the cylinder open, so that their lubrication is similar to that of automobile engines. In the Brunswick machine, there are two piston rings below the suction inlet. These serve to wipe off excess oil and prevent its being drawn into the cylinder.

If the operator neglects these machines and the back pressure drops below atmospheric pressure in the cylinder, this low pressure in the cylinder may result in a considerable quantity of oil, which has been splashed up onto the walls of the cylinder, being drawn in past the rings. This will result in oil losses and oil in the coils.

Some types of compressor cylinders are equipped with a piston box, which has a special arrangement for circulating the oil through it. (See Oil Lantern in latter section.) A small amount of the oil works into the cylinder and lubricates it. The oil in the stuffing-box lantern protects the packing from the action of the hot ammonia gases. The De La Vergne machine is lubricated as above described.

Some compressors are equipped with mechanical lubricators, connected between the intake line and the discharge line. The difference in pressure serves to force the oil through the regulating valve into the intake line.

For the lubrication of the ammonia compressor cylinders, a pure mineral oil of good flash test (365° to 400° Fahr.) and possessing a cold test of 0° to 5° Fahr. should be used. The heat of compression of the

ammonia gas requires that the oil have a good flash test, since it must not vaporize too quickly. The possibility of oil leaking, or being carried in vapor form, with the ammonia gases into the condenser pipes and expansion coils, requires that the oil have a good cold test, to prevent its solidifying in the piping. A fairly low-viscosity oil should be used, one having about 100 viscosity at 100° Fahr for a P. B. oil and 110 viscosity at 100° Fahr. for an A. B. oil, being the best.

STUFFING BOXES.—Hot ammonia gas has a very bad effect on the stuffing-box packing of ammonia compression cylinders. A liberal supply of lubricating oil should be applied at this point, to reduce the possibility of overheating the stuffing box.

OIL LANTERN.—Stuffing boxes on ammonia rods are provided with a chamber called an oil lantern, or sleeve. There are two openings, that connect into this lantern through the stuffing-box walls. One opening, which is usually at the bottom, is connected to the oil supply, which may be a reservoir or a tank, or it may be a hand- or power-operated pump. The other opening is connected into the suction side of the compressor, and is intended to maintain a suction pressure inside the lantern. Care must be taken to see that the correct amount of oil is allowed to go to the lantern. If too much oil is used, the excess oil will pass through the gas-relief line and into the system. Therefore, the lubricator which feeds oil to the lantern must be very carefully adjusted.

Another feature which must be considered is the gas-relief line. Sometimes small particles of rod packing will lodge in the globe valve, which is usually located between the stuffing box and the suction line; and these particles will gradually block up the valve. Then ammonia leaking past between the lantern and the bottom of the stuffing box will keep a high pressure inside the lantern, which will prevent the regular supply of oil from entering the lantern. The ammonia will also flow through the few rings of packing that are located between the lantern and the gland. To correct this condition the relief line must be removed and cleaned.

LOST CAPACITY.—One reason for lost capacity in refrigerating plants is due to the carrying over of the lubricating oil by the ammonia gases and the depositing of this oil on the interior of the condenser and expansion coils. This trouble is due largely to the common mistake of locating the oil separator entirely too close to the discharge of the compressor. The gases at this point are very hot and the oil is mostly in vapor form. If the separator is located near the condenser, where the gases have slightly cooled and some of the oil condensed, it is much easier to prevent an excess of oil being carried into the condenser coils.

MEASURING OIL FED.—All oil used to lubricate the ammonia compressor cylinders should be measured and a record kept. If there is any unusual increase in the amount of oil fed into the cylinders, immediate investigation should be made, to prevent "filling" of the system.

OIL IN CONDENSER COILS.—If lubricating oil has gotten into the condenser coils, it can be loosened by cutting off the water from one stand at a time, and allowing the coil to become hot, when the oil will be thinned and can be run off at the oil trap.

OIL TRAPS.—Oil traps, which may be made of a short piece of three- or four-inch piping, about two feet long, should be located at the lowest places in the expansion and condenser coils.

NOTES ON OIL TRAPS.—A. G. Solomon, in *Power-Plant Engineering,* Vol. 22, No. 12, p. 500: When a compressor or any part of the system is pumped down below atmospheric pressure, be sure that the oil supply to the rod is shut off. * * * Do not empty any oil trap unless it is

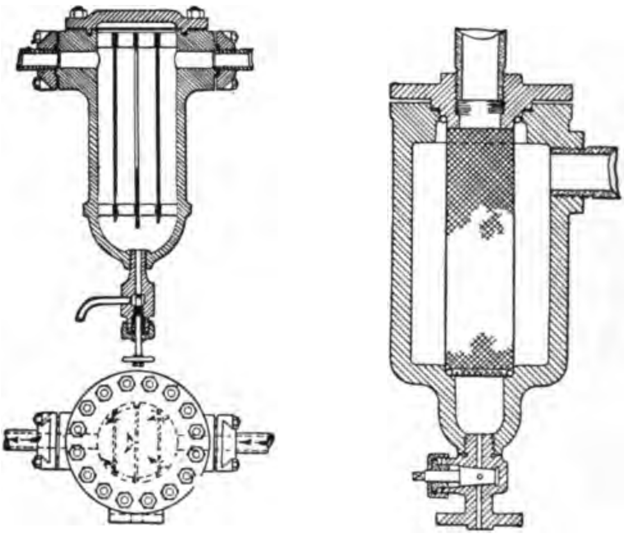

FIG. 1. SEC. 10*hh.*—Types of oil separators, refrigerator systems. (Courtesy Power Plant Engineering.)

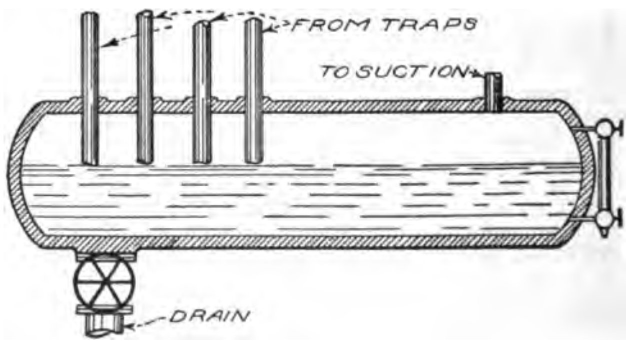

FIG. 2. SEC. 10*hh.*—Ammonia purifying receiver. (Courtesy Power Plant Engineering.)

necessary, and do not blow out ammonia with the oil. * * * The light, frothy-looking oil that is often drawn out contains so much ammonia that the loss is considerable. * * * In a system where it is known that oil is present in the evaporating coils, the discharge trap must also be emptied when any part of the system has been pumped down below usual

working pressure. The lowered pressure causes rapid evaporation of the ammonia, and the oil in the coils will be drawn to the machine. * * * Another time when a large amount of oil may be looked for, is when an ice tank or cold-storage room has been allowed to reach a higher temperature than usual. * * * The bottom manifold, or header, in ice tanks is also a trap for oil, and should be blown out occasionally.

Fig. 1, Sec. 10hh, shows two types of oil separators: *A*, the baffle type; *B*, the wire-screen type.

Mr. Solomon says: In a system containing several traps, it has been found good practice to have a certain day for emptying the different traps. In such a system, an ammonia purifier is almost a necessity; but if a real purifier is not provided, a receiving tank can be made from material which is found around the plant. The drain lines from all the oil traps are connected into the receiver, or purifier, and this, in turn, is provided with a line connecting into the suction side of the system. Blow down all traps into the purifier, and then allow the ammonia to escape in the suction. In this way very little ammonia is lost as the oil is drawn out.

Fig. 2, Sec. 10hh, shows an ammonia purifying receiver.

ICE PLANT SYSTEMS.—The three systems employed in ice plants are: (1) The plate system, (2) the cell system, (3) the can system. The plate and cell systems require a larger plant and cost more. They are not used to any extent in the United States, but are capable of producing clear ice from raw water, and no distillation is required nor is it objectionable should exhaust steam be used, that carries a trace of cylinder oil, with respect to the effect on the finished ice. The can system, which is in common use, requires distilled water, free from colored vegetable, mineral or animal substances, as well as gaseous impurities. Some can-system plants use the exhaust steam for other purposes than to furnish a supply of water for ice-making, in which case the engine cylinder oil carried in the exhaust steam is of no importance. Generally, however, the engine exhaust is used for this purpose, and the exhaust steam must be free from oil. Therefore, an oil which will separate freely from the condensed exhaust steam, in the distilling equipment is required. The purpose of distilling the water in the "can system" is to remove the air, so that it will not be collected in the centre of the cake and make a white core.

STEAM CYLINDERS OF AMMONIA COMPRESSORS

EXHAUST STEAM USED TO MAKE ICE.—The exhaust steam from the steam cylinders is usually condensed, purified, and utilized to fill the freezing cans (can system).

The exhaust steam first passes through a separator to take out the free cylinder oil, then through a feed-water heater to return some of the heat in the steam to the boiler, by way of the feed water. The steam is next condensed, retreated, and the condensed water is skimmed to catch any oil still in it. The condensed water is further filtered, settled, and finally filtered again and piped to the "freezing cans."

STEAM CYLINDER OILS.—Cylinder oils used in the steam cylinders of refrigerating machinery should be pure mineral, uncompounded oils. A mineral cylinder oil is more easily separated from the exhaust steam than a compounded oil. Either a filtered or unfiltered cylinder oil may be used. Absence of compound is the most important requirement to prevent the formation of an emulsion, with the consequent difficulty of removing this emulsion from the exhaust and condensed steam.

SPECIAL CONDITIONS.—In some plants, steam conditions force the use of a compounded cylinder oil, and for these cases it is best to use a filtered oil.

OTHER TESTS.—The cold test, flash test, and viscosities of cylinder oils for use in ice-making plants should be the same as those recommended for steam-engine cylinders under the same steam conditions.

PISTON SPEED.—The piston speeds of the steam end of ammonia compression machinery are usually not more than 400 feet per minute, and the cylinders should, therefore, require a minimum amount of cylinder oil. The smaller the amount of oil used, the easier to prevent trouble from discolored ice.

DISCOLORED ICE.—The most frequent complaint from operators of can-system plants is caused by the discoloration of the ice.

Cause.—If the cylinder oil is not entirely removed from the exhaust steam, it will eventually pass into the freezing cans with the condensed water. Oil discoloration usually shows in the form of a "fan" in the block of ice. The "fan" shape of the discoloration is caused by the oil floating on the top of the water in the can, as the ice freezes from the bottom up.

RUSTED CANS.—Many complaints against discoloration of the ice that are blamed on the lubricating oil, can be traced to the fact that when the plant was shut down some condensed water was left in the freezing cans. Condensed water causes rust to form very quickly, and this rust will cause discoloration of the ice. This condition occurs very often and should always be investigated at once by the oil man adjusting the complaint.

Discoloration from rust may show anywhere in the ice, while cylinder-oil discoloration shows as a yellowish fan-shaped accumulation near the top of the cake. "Red ice" is caused by rust or by the presence of carbonic acid. Lack of attention to the filters is a common cause of discolored ice.

FORM 1 HP

SECTION No.____

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FORM 1 HB

SPECIFICATIONS

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SECTION 10jj

RUST PREVENTION

RUST AND RUST PREVENTATIVES

RUST; ITS CAUSE.—Rust is a chemical action of oxygen upon metal. All metal is porous, and if the pores are filled with moisture or other substances that have an action upon metal, rust will occur. Many times rust will occur under the coating of a rust preventative, due to the fact that the pores contained oxidizing substances before the preventative was added.

RUST PREVENTION.—The material used as a rust preventative must be thoroughly free from water.

A substance must be free from the following properties in order that it may be satisfactory as a rust preventative:

1. It must have good adhesive qualities.
2. It must not have any tendency to roll up.
3. It must not contract after being applied to the surfaces.
4. It should have good penetrative qualities, so that it can penetrate the pores of the metal, driving out all other substances, and by filling them, to prevent the absorption of any others.

All animal and vegetable oils and greases oxidize and liberate free fatty acids, and are, therefore, not suitable for use as rust preventatives. Mineral oils and petroleum greases, which are made without the use of acids, and which are perfectly neutral, make desirable rust preventatives. Greases, which are of a porous nature, are not suitable for rust prevention, as they permit moisture to penetrate the metal pores.

The product used as a rust preventative must be free from staining qualities. The action of light upon hydrocarbons is to liberate the hydrogen, and thus cause the carbon to be deposited; and it is, therefore, necessary to use as a rust preventative a product which will have a minimum "depositing of carbon" effect. This carbon deposit will cause an indelible stain.

USES OF RUST PREVENTATIVES.—Manufacturers of automobiles, ball bearings, all articles shipped in an unprotected state, guns, machine tools, locomotives, etc., all require some form of rust preventative.

Some firms use white lead or tallow as a slushing grease. Gun manufacturers sometimes use sperm or lard oil to protect the interior of gun barrels, gunlocks, files, scientific instruments, etc.

RUST PREVENTATIVES.—For the protection of machine tools and other large pieces where white lead or tallow has been used, a petroleum asphalt, cut back with a hydrocarbon oil, will give good results. It will be found to be superior to a coal-tar product. It is usually applied with a brush. It will dry without becoming brittle, and will not rub off during shipment. It may be removed with kerosene.

RUST GREASE.—Many firms market with good results a No. 4 or No. 5 petroleum grease, or petrolatum for this purpose. It will give good results on polished surfaces.

The Government gives the following specifications for a rust preventative or light slushing oil:

To be used for bright steel surfaces.

It must consist of pure mineral oil, or of such with addition not to exceed 15 per cent. of resin. It must contain no animal or vegetable oils other than resin, and no mineral acid or other substance that will corrode metal. It must be of such consistency that it can be readily applied with a brush at all temperatures to which it will be exposed. The oil will be subjected to an adhesion test as follows: The oil will be smeared on both sides of a copper plate, 2 inches square and .0063 inches thick. This plate will then be suspended by one corner in an oven and maintained at 149° Fahr. for 30 minutes. It will then be cooled and weighed. The increase in weight for the plate must not be less than 65 milligrams nor more than 85 milligrams.

It must be free from all dirt and sediment.

A well-known rust preventative is made by completely neutralizing dark petrolatum and then adding a percentage of potassium chromate.

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SECTION 10kk

SHOE FACTORIES

SHOE FACTORY LUBRICATION

GENERAL CONDITIONS.—There is usually very much waste of lubricating oil in shoe factories. Even in the largest factories, there seems to be no attempt made to keep a check upon the amount of lubricants used or wasted. The floors are usually oil stained, and it is a common sight in those factories having wooden floors to find that the oil from the floor above has dripped through onto the goods being made on the floor below.

The oils and greases should be kept in a convenient storehouse, and the issuing of the lubricants be placed in the hands of a responsible man, to whom all requisitions for oils and greases should be given. In this way the widely varying amounts of oils used by the different rooms of the plants will be evidenced.

It is also recommended, that in order to obtain more satisfactory lubrication, a boy be assigned as oiler for each room. His duties would be to see that the proper lubricants were applied to the different machines in such quantities as they require and no more.

A reduction of the wastage of oil would decrease the fire risk, by reducing the oil staining of the floors.

SHOE MACHINERY LUBRICATION.—*"Clicking Machine":* This machine cuts out uppers. For the eccentric motion use a gear grease or a worm-gear lubricant. For general lubrication use an oil having a viscosity of 240–250 (P. B.) or 325–350 (A. B.), or a semi-fluid grease of one-half consistency of vaseline.

"Channeling Machines": This machine makes the channel for sewing on the welt. It is very high speed, and has open air holes. Use oil having a viscosity of 160–175 (P. B.), or 200 (A. B.), or semi-fluid grease of one-eighth consistency.

"Rounding Machine": This machine has a cam action, a gear action and a gear under a plate with a pantograph motion. Use oil having viscosity of 240–250 (P. B.), or 325–350 (A. B.). or a No. 1 grease.

"Stitching Machine": For these machines use a light oil of about 140–145 Vis. (P. B.).

"Reënforcing Machine for Insole": This is a high-speed machine. Use oil having viscosity of 140 (P. B.).

"Puritan Stitching Machine": Used for reënforcing the canvas. Use a light oil of about 140–145 Vis. (P. B.)

"Insole Tackers": Slow, pinion and gears; also cams. Use oil having viscosity of 275–285 (P. B.), or 375–400 (A. B.), or semi-fluid grease of five-eighths consistency of vaseline.

"Jack Roller": This is used for graining hides for uppers. Use oil having viscosity of 275–285 (P. B.), and other same as for Insole Tackers.

"Large Splitting Machine": Has gears and cone bearings on emery

shaft. For drive shaft use No. 3 cup grease. For other lubrication use oil with viscosity of 275–285 (P. B.), or 375–400 (A. B.), or semi-fluid grease of three-fourths consistency.

"Stapling Machines": Such as J. L. Morrison Company's "Perfection No. 4," equipped with small motor drive, use oil with viscosity of 160–175 (P. B.), or 200 (A. B.), or semi-fluid grease of three-eighths consistency.

"Inking Machine": This is a small, slow, revolving machine. Revolving ink brush, open oil holes. It is used for inking heels. Use same lubricants as for Clicking Machine.

"Burnishing Machine": Used for burnishing heels. Use same lubricants as for Inking Machine.

"Brushing Machine": These are really high-speed lathes. Have open oil holes. Use same lubricants as for Channeling Machines.

"Buffing Machines": Sometimes called a "bottom sander." High speeds. Same lubricants as above.

"Gang Brushing Machines": Open oil holes. High speed. Same as above.

"Counter Moulder Machines": These machines have large cams and gears. For the lubrication use a gear grease, or pinion grease, that is capable of being brush-applied. For the driving pulley, toggle-joint motion, slide, etc., use a lubricant having the same specifications as recommended for the Inking Machine. The lubricant should be of such a nature that there will be no creeping onto the die.

"Butting Machine": Type such as that of Stewart Bros. This is practically a skiver. Use same lubricants as specified for Inking Machine.

"Stamping Machine": Use same lubricants as specified for the above.

"Slugging Machine": This is sometimes called the Loose Nailing Machine. Used for putting slugs into heels. For the general lubrication and cams use same lubricants as recommended for the above machine.

"Tree Machine": This machine has a sprocket and chains, rollers, individual motor drives, open worm gears and bevels. It is important that the shoe be kept free from oil stains, and especially in army trench shoes, where the leather is unfinished. The lubricant for this machine should have no tendency to drip or spatter. Use a semi-fluid grease of five-eighths consistency.

"Tip-Scouring Machine": Has open oil holes. Use same lubricants as for Inking Machine.

"Heel Seat Trimmer": This machine may make 5000 to 6000 R. P. M. It has open oil holes. Use a light oil of 145–150 Vis. (P. B.), or 170–180 Vis. (A. B.).

"Heel Seat Nailer": Has cams. Use same lubricants as Inking Machine.

"Soling Machine": Use same as above.

"Tack-Pulling Machine": For rotary type use light oil of 145–150 Vis. (P. B.), or 175–180 (A. B.). For lever type, use same.

"Inseam Trimmer": High speed. Has cams. Use same lubricants as for Inking Machine.

"Inseam Welt Stitcher": This puts on the Goodyear welt. Use same lubricants as for above.

"Insole and Heel Seat Trimmer": Has speed of about 6500 R. P. M. Use same lubricants as for Channeling Machine.

"*Tip-Scouring Machine*": Use same lubricants as for Inking Machine.

"*Insole Tackers*": Use same lubricants as for above. This machine puts insole on the last. Usually runs poorly lubricated. Has idle pulley and clutch.

"*Lasting Machine*": Puts wire on toe of sole. Has intermittent action. Use same lubricants as for Inking Machine.

"*Marking Machine*": Puts size and marking on soles. Use same lubricants as for above.

"*Toe Trimmer*": Use same lubricants as for Insole and Heel Seat Trimmer.

"*Pull Overs*": Used for pulling uppers onto last and temporarily nailing them. Has idle pulley, clutch and foot pedal. Use same lubricants as recommended for Inking Machine.

"*Nigger Head*": Sometimes called a "Side Laster." Especial attention is called for these machines to the usual custom of allowing the machine to run when no useful work is being done, this resulting in a waste of lubricants and tacks. The lubricant used for this machine should have sufficient body to prevent throwing and spattering, as otherwise the upper leather of the shoe would be soiled. There are cams, open worms, open oil holes, idle pulleys, sliding movements and gears. Use same lubricants as for Tree Machine.

"*Sole Leveling Machine*": This machine brings the sole down to shape. It forms it to the last. It has large, slow cams, and a worm and gear. For the worm and gear use gear grease or worm-grear lubricant, that can be brush-applied. For other lubrication use an oil having a viscosity of 240–250 (P. B.), or 325–350 (A. B.), or a semi-fluid grease of one-half consistency of vaseline.

"*Stitched Separator*": Sometimes called "Prick Stitch." Speed about 540 R. P. M. Open oil holes. Use oil of same specification as for Staple Machine.

"*Rounding Machine and Edge Trimmers*": Speeds as high as 9000 R. P. M. Tendency to throw. Open oil holes. See specifications previously given.

"*Heel Trimmer*": Speeds about 6600 R. P. M. Open oil holes. Same lubricants as Brushing Machines.

"*Sanders*": Sometimes called "Heel Scourers." Speeds about 2280 R. P. M. Use same lubricants as above.

"*Heel Breast Scourer*": Speeds about 3000 R. P. M. Use same lubricants as above.

"*Eyelet Machine*": Use oil having viscosity of 140–150 (P. B.), or 175–180 (A. B.).

"*Crimping Machine*": This is a slow and intermittent machine. Use same lubricants as for Inking Machine.

"*Outsole Stitchers*": The lubricant is fed into the top of this machine, follows down to a slot, against which the needle wipes, by which it is lubricated, and thus prevented from sticking in the hard sole. There are small gears and cams. Black stitching wax is used on the thread. Use same lubricants as for the Inking Machines.

"*Heeling Machine*": Such as the McKay Automatic Loading and Attaching Machine. Has clutch and worm gear on hopper feed. Use same lubricants as above.

"Edge Trimmers": Speeds 12,000 R. P. M. to 14,000 R. P. M. Use same oil as for Eyelet Machine.

"Heel Breaster": Slow, about 100 R. P. M. Use same recommendations as for Inking Machine.

"McKay Heel Compressor": Has gears, train drive, about 75 R. P. M. Has open oil holes. For gears use gear or pinion grease. For general lubrication use same lubricants as for the above machine.

"Pyramid Heel-Building Machine": Use same lubricants as for Inking Machine.

"Heel-Slicing Machine": This machine is equipped with a saw for slicing heels. The saw is driven from a back shaft and pulley. The stock, which has been glued together, is turned by small gears. Use same lubricants as recommended for Inking Machine.

"Sole Cutters": Have idle drive and heavy wheel; also clutch. Use same lubricants as above.

"Splitting Machine and Skiver": Open oil holes. Use same lubricants as for above.

"Rollers": Open oil wells on main drive. 250 R. P. M. Use same lubricants as for above.

"Sole Grading Machine": Such as the Nichols' Evening and Grading Machines, made by the Lacene Manufacturing Co. Has gears, open oil holes. Use same lubricants as for above.

"Sanding Machines": Roll turns at about 3000 R. P. M. Has small gears, idle pulley, open oil holes. Use same lubricants as for Brushing Machine.

"Skiver": This machine splits the sole to a uniform thickness. Has open oil holes. Driving shaft at about 300 R. P. M. Use same lubricants as for Inking Machine.

"Sole Moulder": This is a twin type. It presses soles to shape. Heavy slow speed. Large oil holes. For gears use a No. 4 cup grease. For other lubrication use same lubricant as for Inking Machine.

PAPER BOX DEPARTMENT.—Many shoe factories make their own boxes. The following machines may be found there:

"Cornering Machine": Use oil having viscosity of 240–250 (P. B.), or 325–350 (A. B.), or a semi-fluid grease of one-half consistency of vaseline.

"Scouring Machine": Use same lubricants as for above.

"Die Press": For pasteboard boxes. Use same lubricants as for above.

"Paper Slitter": Use oil having viscosity of 175–190 (P. B.), or 225–250 (A. B.), or a semi-fluid grease of three-eighths consistency.

"Auto Box Machine": Has open oil holes and oil tubes. Also cams and gears. For cams and gears use a gear grease or pinion grease, brush-applied. For general lubrication use same lubricants as for Paper Slitter.

FORM 1 HP

SECTION No._____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
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CALFSKIN TANNERY.—"*Shaving Machine*": This machine shaves the skin. The cylinder is equipped with knives and makes about 2000 R. P. M. Use grease cups and a No. 3 grease, or, in hot weather, a No. 4 grease.

"*Splitter*": This machine has a band knife. Usually oil-cup feed. For feed-roll gears use a No. 3 or No. 4 cup grease. For general lubrication use an oil of 275–280 Vis. (P. B.), or 325–350 Vis. (A. B.).

"*Setting Machine*": The drum-shaft bearings of this machine are lubricated through open oil holes. The machine also has sprocket chain pulleys. The machine is used to straighten out wrinkles in the hides. The bearings should be equipped with grease cups and a No. 3 or No. 4 cup grease used.

"*Common Setting Machine*": This machine has large, slow gears, a big sprocket chain, chain drive to shafts, open-slot bearings on rolls. For chains use a medium gear grease, or a light pinion grease. For general lubrication use an oil having a viscosity of 275–300 (P. B.), or 325–350 (A .B.).

"*Glassing Machine*": This machine is used for polishing the hides. Use for lubrication an oil of about same specifications as for above machine.

"*Embossing Machine*": This machine is used to place the leather under pressure, sometimes as high as 20 tons, and by means of a plate on which the grain has been worked, the desired finish to the leather is given. It has large, slow gears, for which use a medium pinion grease, or general lubrication use oil of same specifications as for the above machine.

"*Measuring Machine*": This machine is used to automatically measure the skin surfaces. Use same lubricant as for above.

"*Coloring Machine*": This machine should be equipped with grease cups and supplied with a No. 3 grease.

"*Buffing Machine*": These are high-speed machines. Usually about 5000 R. P. M. Equipped with open wells. Use same lubricants as for Common Setting Machine.

"*Proctor Dryers*": This machine is equipped with chains to carry the skins on rods through an oven, which is heated to hasten the drying of the skins. For the chains use a pinion grease of high melting point. For the lubrication of the exterior bearings use the same lubricants as for the above machine.

"*Jack Rollers*": These machines have open oil wells and a sliding motion. They should be equipped with grease cups and a No. 3 grease used.

"*Slocum Machines*": This has a brush, which operates at a high speed. Use same lubricant as for Common Setting Machine.

"*Wringing Machine*": This machine is used for wringing out skins. It operates in the proximity of considerable water. Very little lubricant is used on the chains of this machine. For the large gears, semi-enclosed bearings, clutch drive, use a pinion grease that will resist water. For the gear bearings use same oil as used on above machine.

CALFSKIN TANNERY—DYE ROOM

"Vat Gears": Each vat has a paddle wheel, which is turned from overhead shafting by means of gears. Considerable moisture is present. Use a water-resisting pinion grease.

"Unhairing Machine": This machine takes the hair from the hides after the hides have been treated. It is operated at good speed (about 1300 R. P. M.). For oil lubrication use same oil as for Common Setting Machine, but better results can be obtained with grease lubrication.

"Hair Washer and Dryer": This machine has sprockets and chains. There is considerable moisture present. On the chains use a pinion grease having good water-resisting qualities. On the worm gear use the same.

SOLE LEATHER TANNERY

"Jack Roll for Sole Leather": Use grease-cup application, supplied with No. 3 grease.

SECTION 10LL
SHIPYARDS

SHIPBUILDING PLANTS AND THEIR LUBRICATION

The lubrication of shipbuilding plants involves the lubrication of a power plant, a plate and angle shop, pneumatic tools, and shipways, when a ship is to be launched.

The chief products and the places requiring lubrication are as follows:

Power plant:

- Steam cylinder oil for main engines.
- Steam cylinder oil for water pumps, steam end.
- Steam cylinder oil for vacuum pump.
- Steam cylinder oil for compressor (air).
- Engine oil for main engines.
- Engine oil for water pumps.
- Engine oil for vacuum pumps.
- Engine oil for air-compressor bearings.
- Dynamo oil for alternator bearings.

Plate and angle shop:

- Black oil for die and plate oil.
- Cup grease for pneumatic tools .
- Lubricants for pneumatic tools.

Tool room:

- Light cold-test oil for oiling pneumatic tools.
- Tempering oil for tempering tools.

Shipway:

- Launching grease.
- Black oil for chains, etc.
- Pinion grease for crane bearings.
- Cup grease for crane bearings.

The cylinder oils for the steam cylinders and pumps should be selected as required by the steam conditions, and with particular attention to the boiler feed-water conditions, as the water for making steam in shipbuilding plants is usually drawn directly from the river. The selection of these oils is covered in the chapter on that subject. The air compressors in these plants are usually large and well loaded. A heavy air oil is usually required, such as light filtered blended stock (525° F. Flash, 300–315 Vis. at 100° F.). The pneumatic hammers are generally kept in a tool room, where the oiling is attended to. Dark petrolatum, or a soft grade of cup grease, will fill their lubricating wants in summer, and a filtered cylinder stock (105 Vis. at 212° F.) will give good results in winter for drills, etc. For other pneumatic lubrication see index.

SHIP LAUNCHING LUBRICATION

LAUNCHING GREASE AND ITS USE.—Fig. 1, Sec. 10LL, shows a longitudinal view of a ship with its launching cribbing in place, and Fig. 2, Sec. 10LL, a sectional view of the vessel, showing the various parts of the launching equipment at the point the section was taken.

A description of the various steps of preparing the ship for launching is given as follows: When the vessel is started, the "keel blocks" are laid at intervals of two or three feet, rising at an easy angle from the water's edge and getting shorter as they recede from the water line. The blocks rest on the "capping," which is in turn carried by the foundations. (These may be piling, or, in some shipyards, concrete foundations are used.) The keel is laid on this inclined plane, and after the ribs are bolted on, the inside framework and plates are put in place and held up by "bilge shores," as shown. This leaves two unobstructed tunnels on either side of the line of keel blocks, which will be used as later described.

When the time approaches to launch the ship, "launching blocking" is placed, as shown in the figure, and then the "groundways," which are usually kept floating in the water nearby, are towed to the desired point

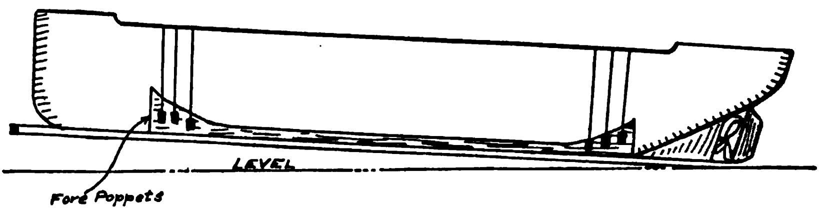

FIG. 1. SEC. 10LL.—Side view of ship and launching ways.

and are pushed under the ship, and are spiked down to the "capping." Then the "sliding-ways" are placed on "groundways." Wedges are put on top of the sliding-ways, then blocking, and above that "cribbing" is placed, which is made to take the shape of the ship.

When this has been shaped up and a short time before launching, the sliding-ways are pulled sideways in sections, and first stearin and then the tallow, and last a layer of the launching grease is applied to the groundways. The sliding-ways are then slid back into position and are held in place by "thropping," which is usually steel cable or Manila roping. The groundways are equipped with siding, as shown, to keep the sliding-ways from leaving the track. Next the wedges, above described, are driven in a little way under the cribbing, to make it take some of the weight of the ship. Then, say, every fourth bilge shore is knocked out, and the wedges are driven in further. Then more shores are removed, and the wedges driven in further, until the cribbing is carrying practically the entire weight of the ship. The sliding-ways are also held from slipping by "sole pieces," and sometimes by huge chains.

At the launching time, the remaining shoring and scaffolding are removed, the wedges are driven home, ship carpenters crawl under the hull and knock out the keel blocks. Then the sole pieces are sawn and the ship starts to move.

The launching grease only acts as a preliminary lubricant, and the tallow and stearin are depended upon to carry the greatest part of the friction load.

The cribbing is equipped with ropes as well as the wedges, so that after the ship has been launched these materials may be recovered. The tallow and stearin are also fished out of the water, and scraped from the ways as much as possible.

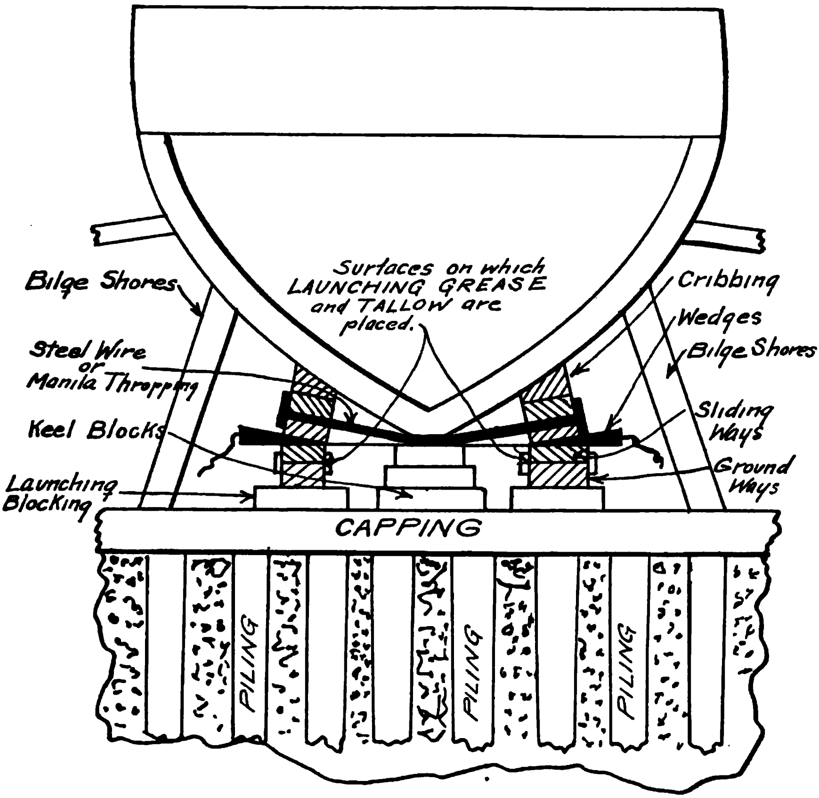

FIG. 2. SEC. 10*ll*.—Cross sectional view of ship and launching ways.

It will be noticed, that when launching a ship, rarely any smoking, due to high friction, will be seen until the stern of the boat is well into the water. Then, due to the fact that that end of the ship which is carried by the water has been lifted from the ways, the front end of the cribbing must carry about one-half of the weight of the ship on a small area. This is provided for by making the front end of the cradle, or, as it is called, the " fore poppets," very strong.

Thus the high frictional heat developed, due to the decreased area and increased load, places a severe test on the launching lubricants.

The following amounts of material were used for launching the ships as shown:

FIG. 3. SEC. 10*ll*.—**Ship going down ways. Note men collecting used tallow for reclaiming.**

7000-ton ship:

500 pounds stearin.
250 pounds launching grease.
2500 pounds tallow.

Three 4000-ton ships:

4000 pounds tallow.
1000 pounds launching grease.
1000 pounds stearin.

A regular grade of No. 3 or No. 4 cup grease has been used with success as a launching grease. There are a number of special greases on the market, which, on examination, prove to be an ordinary cup grease, which has been colored with dye to throw the consumer off the track as to its real character. After the launching, it is often possible to recover a part of the stearin and tallow.

The ship shown in Fig. 3, Sec. 10LL, has just started down the ways. Note the men already after the used tallow and stearin that has been left on the ways. This material is collected and reclaimed.

The amount of launching grease used varies with the time of year and according to the atmospheric temperature.

SECTION 10mm

SOAP MAKING

The following general descriptions are intended merely as elemental notes, and the reader is referred to more comprehensive books on the subject for specific data.

GENERAL.—There are two main types of soaps—hard soap and soft soap. Soap is generally made from such fats and oils as lard oil, olive oil, palm oil, cocoanut oil, castor oil, tallow, etc. Also bean oil (soya), which is used in cheap soaps, after the glycerin has been extracted; peanut oil, to take the place of olive oil; cottonseed oil, linseed, etc. Usually the Ceylon grade of cocoanut oil is used in high-grade soaps, leaving the glycerin in white soaps. Soya bean fatty acids are used as a substitute for olive oil foots, and are said to be about as good, except where color is important. Olive oil foots are used in textile soaps and softeners. Fish oils, whale oils, etc., are also used for some purposes.

When boiled with caustic soda, caustic potash, or lime, the fats are decomposed and two bodies are formed. One is glycerin and the other is soap. This operation is called saponification. The fats and oils have a basic radicle, which is called glyceryl, and one or more, usually not less than two, acid radicles. In the operation of boiling with caustic soda, or caustic potash, which are strong bases, the radicles are interchanged, and the soda or potash take out the fatty acid or acids from the oil or fat, and the product thus obtained is soap, caustic soda giving hard soap and caustic potash giving soft soap. The basic radicle, as mentioned above, is separated out in the form of glycerin. The process described is, as stated above, known as saponification, and the oils that are capable of being saponified are known as saponifiable oils. Furthermore, the fact that the fatty oils or fats yield glycerin on being saponified, has given them the name of glycerides. The caustic soda, or caustic potash, is called an alkali.

In general, there are three methods of making soap: (*a*) The fats and the alkalies may be boiled together in open kettles; (*b*) The fats and alkalies may be combined and boiled under pressure in closed kettles; or (*c*) The fats and alkalies may be combined at atmospheric temperature. In the (*a*) process, the soap is boiled with an alkali solution until the saponification is completed. Then, for a hard soap, salt is added, which causes the soap to be thrown down as curds. These are collected and allowed to set in a form. In process (*b*) the fats and alkali are boiled in a closed kettle under a pressure until saponification is completed, when the soap is set aside to cool. In process (*c*) the fats are melted and mixed with a strong alkali solution, and after allowing a sufficient time for the saponification to become complete, the soap is ready.

In the boiling process (*a*), as before stated, the fats and the alkali are brought together in the presence of water. The proportions vary.

FORM 1 HP

SECTION No._____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
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according to various formulas. A general description of the process is as follows: A little weak lye is run into the soap pan and is heated, by means of a steam coil, until near boiling, when some of the fats that are to be saponified are run in, after having been previously melted. Next there is run in soda lye, and steam is turned on to bring the mixture to a boil. After the batch has appeared to have come together, the remainder of the oil and lye is added, stirring with a paddle or a mechanical stirrer until the saponification is found to be complete, and the batch has a smooth, homogeneous appearance and drips off the paddle in clear flakes. Salt or strong brine is then thrown into the pan, which separates the soap from the water used in the boiling and from the excess alkali, and also from the glycerin formed when the saponification occurred. After sufficient salt has been added, the steam is shut off and the batch is allowed to rest for several hours, after which the batch will have settled out into layers, the upper layer containing the soap and some percentage of water, and the lower layer consisting of spent lye. The lye is run off. The soap is then run into a pan with a small quantity of lye, and the two are boiled for several hours, for the purpose of completing the saponification and preventing any unsaponified fat. After boiling, the soap is allowed to settle for several days, to separate the soap and lye. The soap is then put into a frame to set and cool. This gives what is known as curd soap. There are several other types of soaps produced by this method by altering the treatment.

In the cold-made soap process, the fats are run into the pan and melted, and then lye is run in, while the batch is constantly stirred. After the lye and oil have been well mixed, the batch is run into frames and left for the soap to form.

In the manufacture of a soft soap, the fats and alkali are boiled together until saponification is complete. Potash is used as an alkali, although sometimes a little soda may be used. The soft soap is usually amber-colored to red-brown, and about the consistency of lard. In some cases it is desirable to have the soap "fig." "Figging" is indicated in soft soap by streaks of white, usually radiating from the sides of the container inwards. It is said to indicate a high quality of soap, and is said by some makers to be due to the presence of stearate of soda, which crystallizes out when the soap cools. Some of the oils used to make soft soaps are cottonseed, whale, linseed, olive, and tallow. For white soaps, tallow, cocoanut oil, or lard may be used. Some of the soaps have the following characteristics: Cottonseed oil varies from golden to amber, and is said to be apt to turn rancid on keeping. Olive-oil soap varies from amber to greenish. Whale oil gives a fishy-smelling soap of a reddish color. Linseed oil gives an amber soap. Tallow gives a stiff soap and lard gives a white soap that is not quite so stiff as tallow soap. Sometimes resin is used in soaps because of its detergent quality.

OUTLINE OF METHOD OF USING MINERAL SOAP OILS.—A typical method is as follows: About 3 per cent. of mineral stock is added to the tallow and grease, and is put into the kettle when stocking. The amount of resin is not increased. When the soap is placed in the crutcher, 90 or 100 pounds of sal soda, 35–37 strong, and 25 pounds of mineral soap stock is added. This is crutched thoroughly, and then examined to determine whether it is too strong or too weak. If too weak, a little more sal soda is added until it is brought to the desired strength, and if too strong, mineral stock is added. When the soap is worked up perfectly and not too hot, it is run into the frame, then cut and racked as soon as possible, especially in cold weather.

If silicate of soda is used, it must be added before the sal soda, and "N" or "K" quality is preferred, without heating. The best plan is to depend upon the mineral oil to remove strength in the crutcher, that is if it is not salt strength. It is best not to use salt in the change before the pitch, as it is difficult to remove and would show in the crutcher. The soap should be well up to strength before framing. If the pitch is left too weak, the soap will not settle the nigre sufficiently to take the sal soda. and if left strong, the soap will be thin and will settle out better and give a more translucent soap. This is an advantage of mineral soap oil over animal and vegetable oils, because only a very small portion of these oils would saponify readily enough to change in the crutcher.

Mineral soap oil is capable of neutralizing an amount of caustic or carbonated strength. A feature in favor of mineral soap oil is, that it will not become rancid or injure the soap while drying. It also has healing and detergent qualities, and will also prevent to some extent the soda from showing on the surface of the soap.

The soap can be rendered milder and will have qualities less liable to chap the hands, in case the pitch is left strong, by adding mineral oil before the sal soda, so that the caustic, instead of the carbonated strength, will be neutralized.

Of course, the above description pertains to sal-soda soap. However, with the exception of mottled soap, mineral soap stock can be crutched into all soaps with profit and a finish obtained that is very hard to get in any other way.

MINERAL SOAP OILS.—A pale paraffin oil of about 100 Vis. Saybolt at 100° Fahr. will make a good-bodied soap oil or stock, while a lighter grade would be obtained by using a pale paraffin oil of about 60 to 70 Vis. Say. at 100° F.

Notes. Three per cent. of mineral soap oil to the entire weight of stock and lye is used by some concerns to give cold-made soaps the feel and appearance of boiled soap.

A greater percentage of sal soda and mineral oil can be crutched into cold-made soaps by allowing it to stand sufficiently long in the frame to become thoroughly saponified, then remelt and crutch the same as for settled soap. The crutching should be continued until the soap was stiff enough to hold the sal soda, and silicate, if any is used, in suspension, but no longer, because the stiffer the soap, the rougher it will cut up.

When the soap is run into the crutcher and after the sal soda is added, the crutcher should be run until the soap works up perfectly smooth and bright, when it is ready for the mineral oil. However, if a small sample

of the soap is dull when cooled, more sal-soda solution must be added. The soap should be perfectly smooth and close before the mineral oil is added. If any perfume is required it is added at this point. Usually the soap is framed at about 140° Fahr., but if it contains much resin, the temperature of the framing should be lower, or approximately 130° Fahr.

If silicate of soda is used (generally " N " quality), it is run into the crutcher cold and thoroughly worked into the soap before the mineral oil is added.

If the manufacturer desires to make settled soap, with and without sal soda, the mineral stock is very useful for removing the excess of caustic strength, to give room for the sal soda, thus making the two kinds of soap from the same batch.

A soap stock made by a well-known refiner had the following approximate tests: Viscosity Saybolt, 35 at 212° F.; cold test, 95° Fahr.; flash, 400° F.; gravity, Baumé, 32–33.

GENERAL DATA.—Saponification is the term applied to splitting of an " ester " by the action of water forming an alcohol and a fatty acid. (Glycerol is the alcohol in fats.) This may be expressed as follows:

$$\underbrace{C_3H_5\,(O.C_{18}H_{35}O)_3}_{\text{Stearin}} + \underbrace{3H_2O}_{\text{Water}} = \underbrace{C_3H_5(OH)_3}_{\text{Glycerol}} + \underbrace{3C_{18}H_{36}O_2}_{\text{Stearic Acid}}$$

The stearic acid can then be neutralized with alkali to form soap as follows:

$$\underbrace{C_{18}H_{36}O_2}_{\text{Stearic Acid}} + \underbrace{NaOH}_{\text{Sodium Hydroxide}} = \underbrace{H_2O}_{\text{Water}} + \underbrace{C_{18}H_{35}O_2Na.}_{\text{Sodium Stearate (Soap)}}$$

The oldest method is to treat the fat itself with alkali, instead of splitting the fat into glycerol and fatty acid, then neutralizing with alkali, as following illustration:

$$\underbrace{C_3H_5\,(O.C_{18}H_{35}O)_3}_{\text{Stearin}} + \underbrace{3NaOH}_{\text{Sodium Hydroxide}} = \underbrace{C_3H_5\,(OH)_3}_{\text{Glycerol}} + \underbrace{3C_{18}H_{35}O_2Na}_{\text{Sodium Stearate}}$$

SECTION 10nn

STEAM CYLINDER LUBRICATION

THE LUBRICATION OF STEAM CYLINDERS

The proper and satisfactory lubrication of the valves and cylinders of steam engines offers one of the most difficult problems met with in practical lubrication.

Steam cylinder lubricants must perform their work under the most unsatisfactory conditions and in an inaccessible place, where the detection of poor lubrication is difficult.

The cylinder lubricant must first be atomized by the incoming steam and then carried to the cylinder walls and valve seats. These surfaces are in a most unfavorable condition to receive the lubricant, as they are hot and wet.

The wiping effect of the piston and valve tends to destroy the film of lubricant, since their motion is in a straight line, and the washing effect of the water of condensation also aids in the destruction of the film.

The following conditions have an important bearing on steam cylinder lubrication:

1. The kind of engine.
2. The steam pressure.
3. The condition of steam (wet or dry).
   (*a*) Superheat (how much?).
4. The rubbing speed of piston.
5. The method of feed of the cylinder lubricant.
6. The diameter of the cylinder.
7. The location of the separator and distance of the engine from the boiler and the condition of the pipe covering of the steam line.

KIND OF ENGINE.—The information required under this heading is intended to indicate the kind of valve and valve gear of the engine; *i.e.,* Corliss, plain slide valve, piston valve, etc.

These valves are described in the section of this book referring to steam engines, and their mechanical construction requires individual consideration of their lubricating requirements.

STEAM PRESSURE.—Steam having a temperature due only to its pressure* is called "saturated steam."

Steam which has been heated to higher temperature than that due to its pressure alone, is called "superheated steam."

The pressure, of the steam supplied to a steam cylinder, is an important guide in the selection of a lubricant for that cylinder. By reference to standard steam tables, the temperature of the steam may be directly determined if the steam is "saturated," and may be obtained by adding the number of "degrees superheat," if the steam is superheated. Table A

* See index for other data on Steam.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

gives the approximate temperatures, to the nearest full degree Fahr., for saturated steam at various gauge pressures.

TABLE A*

GAUGE PRESSURES AND NEAREST FULL DEGREE TEMPERATURES FOR SATURATED STEAM

Gauge pressure, pounds per square inch	Temperature Fahr.	Gauge pressure, pounds per square inch	Temperature Fahr.
1	216	125	352
5	227	130	355
25	267	140	360
50	297	150	365
60	307	160	370
70	316	170	375
80	323	175	377
85	327	180	379
90	331	190	383
95	334	200	387
100	337	215	393
105	341	235	400
110	344	245	404
115	347	265	411
120	350		

NOTE. The nearest full degree is taken as being accurate enough for use in practical lubrication, and the table is, therefore, only approximate.

NORMAL STEAM TEMPERATURES.—It will be noticed, by reference to the steam table, that the temperature of saturated steam, at pressures even as high as 265 pounds, is only 411° Fahr.

Any petroleum cylinder oil will have a flash test exceeding this temperature, so that for normal steam conditions—that is to say, with no superheat—no particular attention need be paid to the flash test of the oil.

SUPERHEATED STEAM.—Superheated steam is described as having a number of "degrees superheat." This refers to the number of degrees Fahrenheit, by which the temperature of the steam exceeds the normal temperature of saturated steam at the same pressure.

The temperatures of superheated steam range as high as 60° Fahr., and sometimes exceed even that temperature.

Superheated steam does not contain any moisture. Steam is superheated to increase the economy of the engine by reducing the number of pounds of steam or water required by the engine per horse-power per hour.

Due to the lack of moisture and high temperatures, steam cylinders using superheated steam are subjected to different conditions from those met with in cylinders using saturated steam.

The chief requirements for a cylinder oil to be used for the lubrication of cylinders using superheated steam are high flash-point and good body.

Since there is practically no moisture from condensation water in cylinders using superheated steam, it is recommended that the cylinder

* See index for other steam tables.

oil used be a straight mineral uncompounded oil. It should be unfiltered and have the highest possible viscosity and flash-point.

The usual cylinder oil for this purpose has a viscosity of 315° to 325° Say. at 212° Fahr. and a flash-point of 625° to 640° Fahr.

A steam cylinder is alternately a condenser and a boiler. The cylinder walls are heated by the heat given up by the steam due to condensation, and the condensed water is boiled again and largely vaporized during the exhaust. Cylinder oil is, therefore, compelled to resist the "washing effect" of the condensation water by emulsifying with it, and then to resist the vaporizing effect to which it is subjected during the exhaust stroke.

In many steam cylinders there will be from 1/4- to 3/4-inch depth of condensation water on the bottom of the cylinder. Often this depth will be exceeded to a depth of 1/2 inch, and it is not an unusual case to find the low-pressure piston of a compound engine practically running in water.

CYLINDER-OIL COMPOUNDS.—In order to aid the emulsification of cylinder oils with the condensed steam, they are compounded with acidless tallow oil, and in some of the inferior oils with "degras" (wool grease). Neatsfoot oil is also used for this purpose.

* Acidless tallow oil should always be used for compounding. The cheap and deposit-forming degras is not recommended.

The percentages of tallow oil used for compounding purposes will run from 3 per cent. for ordinary dry saturated steam conditions to 10 per cent. for low pressures and wet steam and long-uncovered steam lines, where the percentages of moisture in the steam will be high.

CYLINDER CONDENSATION.—The amount of condensation in a steam cylinder depends upon the range of temperatures of the steam; that is, difference between the temperatures of the admission and exhaust steam.

The time of "cut-off," whether early or late in the stroke, and the speed of the engine affect the amount of condensation. Engines using the same quality of steam and running at 400 R. P. M. are found to have only about one-half the relative amount of condensation as is found in engines running at 100 R. P. M.

TEMPERATURE RANGE.—The temperatures of steam cylinder walls fluctuate. Some authorities have stated that this temperature range may approach one-half the steam temperature range. This theory is under dispute as to the amount of range, but the fact remains that there is a considerable fluctuation in these temperatures, which has a resulting effect upon the viscosity of the cylinder lubricant.

VISCOSITY OF OIL IN THIN LAYERS; EFFECT OF HEAT ON.—Richardson (*J. Soc. Chem. Ind.*, 24, pp. 315–319, 1905) and Hanson state: In an atmosphere of superheated steam, the change of viscosity of oil in thin layers when heated at temperatures varying from 100° to 201°, the changes were exactly similar to those in air.

Worrall and Southcombe (*J. Soc.*, 27, p. 308, 1908) state that in cylinders heated as high as 750° F. steam causes no chemical change in the oil. The horny, or granular, deposit found in cylinders is Fe_2O_3 or Fe_3O_4 cemented together by oil.

RUBBING SPEEDS.—The rubbing speed of the piston has an im-

* NOTE. See page 892 for effects of free fatty acids on steam cylinder lubrication.

portant effect upon cylinder lubrication. The piston speed affects the amount of condensation, and also is a gauge of the wiping effect existing within the cylinder.

When a low-speed engine is supplied with wet steam, the amount of condensation water to be met with will be high and the lubricant must be "adjusted" to meet it. In the case of high-speed engines, the amount of condensation water, under normal conditions with the same wet steam, is much lower.

METHODS OF FEED.—Proper location of the feed pipe of the cylinder-oil lubricator is very important in securing good atomization of the oil.

The best results cannot be secured, even with other favorable conditions, if the oil is fed into the steam between the throttle valve and the cylinder, or directly on top of the valves. This method of feeding does not favor the atomization of the oil, which is most necessary in order to secure the proper distribution of the lubricant over the surfaces to be lubricated. The cylinder oil, under these conditions, will mostly pass out with the exhaust.

Cylinder oil should be fed into the steam line at least three feet above the throttle valve, thereby insuring proper and complete atomization. The oil should be introduced into the steam line by means of a slotted pipe, as is shown in Fig. 1, Sec. 10nn. The end of the feed pipe should extend to just past the middle of the steam pipe. This feed pipe should be slotted on the bottom, as shown. If the feed pipe is screwed into the steam line flush with the inside surface, the oil will spread over the inside of the steam line and only a small amount of it will become atomized and be available to lubricate the cylinder and valve.

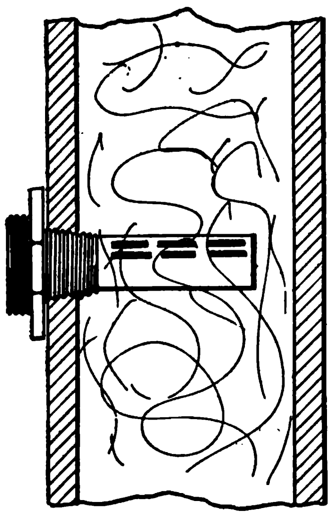

Fig. 1. Sec. 10nn.—Method of admitting cylinder oil to steam line.

DIAMETER AND STROKE OF THE PISTON.—This data is of value merely as a gauge as to the proper amount of oil that should be supplied to the cylinder, as from this data and the piston speed, the total square feet of surface rubbed over per day by the piston may be obtained and comparisons made with other similar engines, to check the relative amounts of oil used.

LOCATION OF THE SEPARATOR.—The location of the steam separator should be as near the throttle as possible, so that the steam will be dry. The separator should have a safe margin of capacity.

The distance from the boilers to the engine has an effect upon the amount of moisture in the steam. Long-uncovered steam lines are productive of wet steam. The pipes should have sufficient pitch downwards towards the engine so that the condensed water will flow in the same direction as the steam, and thus tend to flow into the separator, or drip, instead of running against the flow of the steam and being picked up by it, with a resulting large amount of water in the steam.

STEAM-CYLINDER LUBRICATORS

There are two general types of cylinder lubricators, *i.e.*, the hydrostatic or displacement lubricator and the forced-feed lubricator.

HYDROSTATIC LUBRICATORS

PRINCIPLE OF HYDROSTATIC LUBRICATORS.—A drop of water admitted to a tank containing a lighter fluid must displace an equal volume of that fluid. A column of water exerting its weight to displace a lighter fluid is the force which operates the hydrostatic lubricator. This force is measured by the height of the column of water, and is not affected by the steam pressure, as in any properly designed lubricator; the steam pressure on top of this column and at the point of discharge of the oil from the sight-feed chamber is the same, or equal. In operation, the pressure within the lubricator-oil reservoir is equal to the boiler pressure, plus the weight of the column of water in the condenser, while the condenser, equalizing pipes, sight-feed chambers, and delivery pipes are under boiler pressure. Therefore, the water from the condenser, under the pressure of a practically constant head, enters the oil reservoir, through the water valve, displacing the oil and forcing it drop by drop through the sight-feed chamber to the discharge point.

Fig. 2, Sec. 10nn, shows a well-known hydrostatic lubricator.

The operation of this lubricator is as follows: Steam from the steam line is admitted to the exposed connecting pipe *D*, which should be at least five feet in length for the quart-size lubricator. In this pipe the steam is condensed and the hydrostatic pressure of the condensation water causes the oil, which is on top of the water in the body of the lubricator, to pass down through the pipe *B*, up through the sight-feed glass *E* and into the steam line through the pipe *H*.

CARE OF HYDROSTATIC LUBRICATORS.—All connections must be perfectly tight. Clogging of the sight-feed glass is sometimes due to the rubber ring at the bottom of the glass having been squeezed. over the outlet into the glass, or waste, may have gotten into the outlet. The remedy is to remove the glass and clean the outlet.

Oil trailing up the side of the sight glass is usually due to a denting of the cone, which is located at the bottom of the glass. The remedy is to file down the cone, solder a fine wire to the side, and permit it to extend nearly to the top of the glass. The oil will then follow the wire and the glass will remain clean.

To reduce the size of the drops of oil being fed by the lubricator, fill the sight glass with glycerin, or a solution made of a teaspoonful of common table salt and the desired amount of water. The increased gravity of the fluid in the glass will cause the drop to break off from the cone before it has become as large as it would have become with straight water in the glass.

TO CLEAN THE FEED GLASS.—Remove the plug at the top of the upper connection and swab out the glass with a piece of waste, which has been soaked in kerosene and attached to a stick.

NOTES ON HYDROSTATIC LUBRICATORS.—Never allow the lubricator to run empty, as the glass will get hot and cause oil to stick to

it. In the engine-room, cylinder oil is usually kept limpid by placing it in a coffee-pot and allowing it to stand on top of the engine cylinder. A piece of asbestos should always be kept under the pot to prevent overheating and consequent injury to the oil.

"Churning" is caused by partially filling the lubricator with oil,

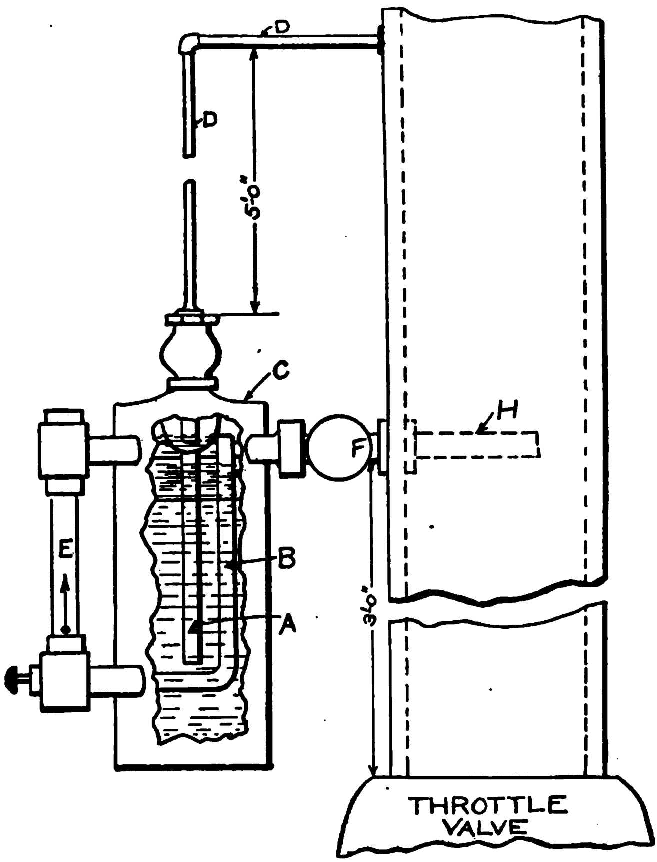

FIG. 2. SEC. 10nn.—Typical hydrostatic cylinder lubricator.

and then if there does not happen to be enough condensed water in the lubricator to make up the rest of the capacity, steam will flow in and mix with the oil and churn it into a foam. When this occurs, empty the lubricator, allow it to cool, and refill it with oil and allow sufficient time for the formation of the proper amount of condensation water.

Leaky joints cause irregular feeding.

LUBRICATORS FOR COMPOUND CONDENSING ENGINES.—Cylinder lubricators, for use with compound engines operating with a pressure below atmosphere in the low-pressure cylinder, should have spring-loaded check valves on the discharge side of the lubricator. Otherwise the low pressure may cause the oil to be drawn out of the reservoir into the cylinder in such large quantities that there will be undue waste.

FORCED-FEED CYLINDER LUBRICATORS

These lubricators consist of an oil chamber to which is attached one or more pumps, which are actuated by some reciprocating part of the engine. Forced-feed lubricators are positive in their action and are automatic in their feed. As the engine speeds up, they will increase the feed to carry the increased demand upon the cylinder lubricant. They require very little attention.

Fig. 3, Sec. 10nn, shows the well-known type of Rochester automatic lubricator. Fig. 4, Sec. 10nn, shows two sextuple feed Rochester lubri-

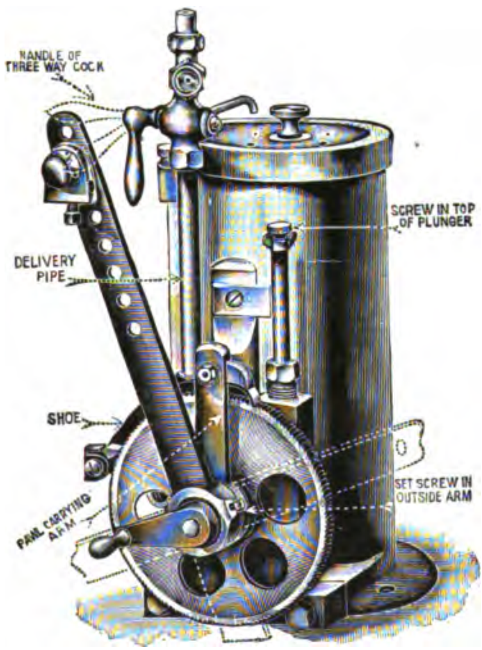

FIG. 3. SEC. 10nn.—Rochester automatic cylinder lubricator.

cators, attached to a pair of four-valve hoisting engines built by the Vulcan Iron Works.

Fig. 5, Sec. 10nn, shows a two-feed Phenix forced-feed lubricator, which is provided with a divided tank for holding two kinds of oil. Fig. 6, Sec. 10nn, is a sectional view of the Phenix forced-feed lubricator, which shows a pumping unit. One of these pumping units is provided for each of the feed lines.

A short description of this type of lubricator is of interest and is, therefore, included, as follows: Referring to Fig. 6, Sec. 10nn, a shaft that runs the entire length of the lubricator is driven by a lever and ratchet. Eccentrics are provided on the shaft, which give a vertical up-

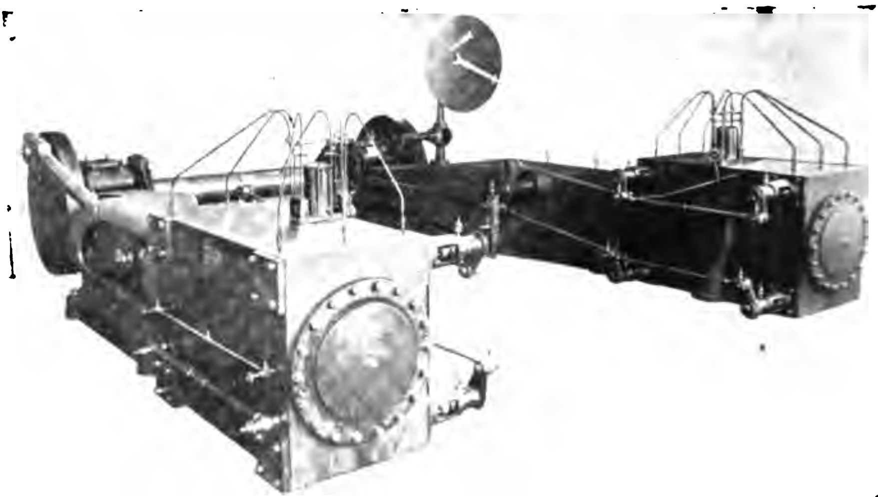

FIG. 4. SEC. 10nn.—Sextuple feed Rochester automatic lubricators attached to a pair of four-valve hoisting engines.

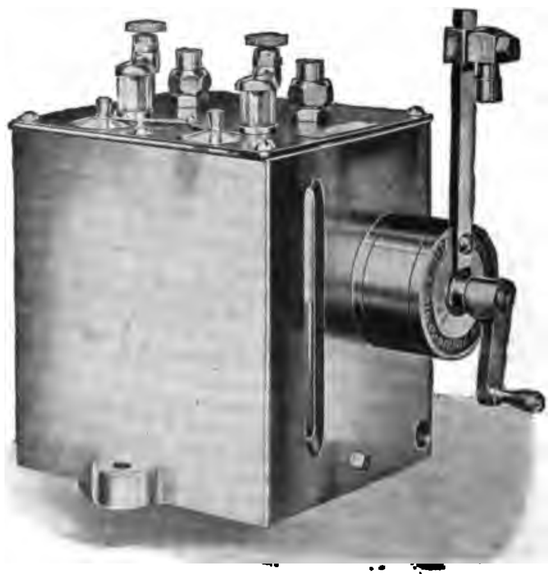

FIG. 5. SEC. 10nn.—Two-feed Phenix forced-feed lubricator.

and-down movement to each pumping unit. Each unit is a double pumping unit, composed of a lower pump, which measures out a definite quantity of oil and forces it up through the sight-feed glass, from which the upper pump draws it and forces it out through the feed line. A sleeve carried upon the lower pump plunger may be adjusted to regulate the amount of oil fed for each stroke of the pumping plungers. When the sleeve is in its highest position, the entire amount of oil drawn in by the lower pump is forced out into the sight-feed glass, and when the sleeve is at a lower position, the pump plunger does not travel to the end of the

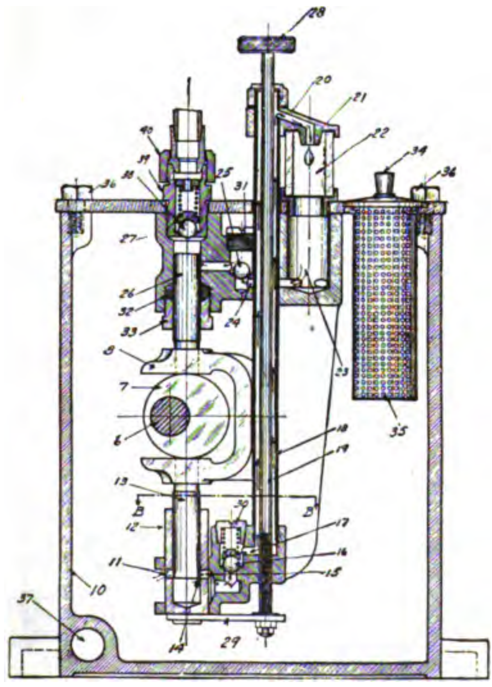

FIG. 6. SEC. 10nn,—Sectional view of a Phenix forced-feed lubricator body and a pumping unit.

cylinder, and the amount of oil forced out is thus reduced. The location of the sleeve is regulated by the milled nut on top of the pump casing.

Fig. 7, Sec. 10nn, shows a Richardson, model "M," lubricator for steam-cylinder lubrication.

Referring to section *ZZ*, the oil is withdrawn from the reservoir through a foot valve *A*, by means of plunger *B*, which delivers the oil through the circulating galley *C*, into which the drip nozzles *R* open. The amount of flow through each drip nozzle is regulated by the setting of the needle valve *M*. The surplus oil not passed through the feed nozzles *R* returns to the reservoir through the overflow ball-check *D*. Driving lever *J* actuates

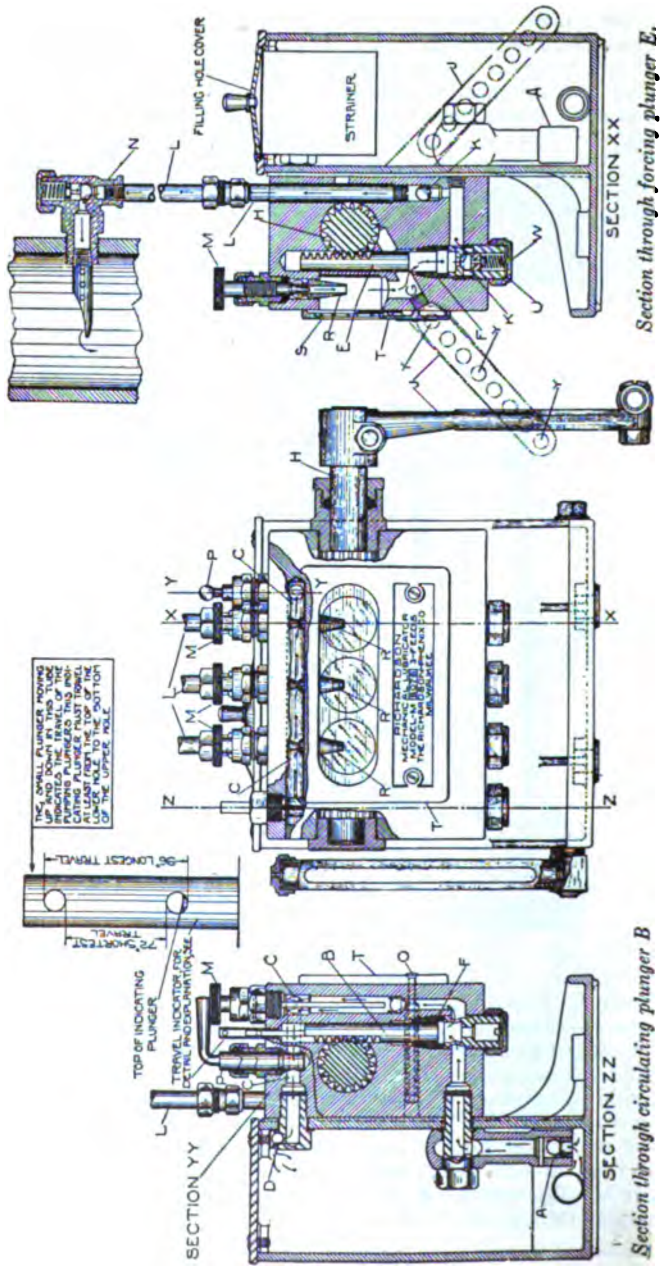

FIG. 7. SEC. 10RR.—Section of Richardson lubricator.

the plungers E through the common gear shaft H. The plungers E move up and down with each revolution of the engine, and at each downstroke feed a small amount of oil from the chamber G, and force it out through the check valves KK into the feed line L, and past the terminal check valve N to the delivery point. The feed lines are always full of oil, up to the check valve N.

The driving lever J requires a reciprocating movement of from 72° to 96°. The travel of the lever J can be adjusted by attaching the driving-

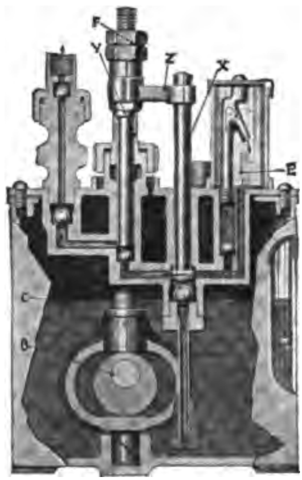

FIG. 8. SEC. 10nn.—Sectional view of McCord forced-feed lubricator.

rod pin in the wrist-pin holes. The travel of the oil-pumping plungers is shown by the travel indicators on top of the lubricator. The shortest travel must not be less than from the top of the lower hole to the bottom of the top hole. The longest travel must not be more than from the bottom of the lower hole to the top of the upper hole.

Fig. 8, Sec. 10nn, shows a sectional view of a McCord forced-feed lubricator.

EXAMINATION OF STEAM CYLINDERS.—A well-lubricated cylinder ought to appear dark and smooth, with no signs of bright polish when the cylinder head is removed.

A slight rubbing with a piece of tissue paper should produce a bright polished surface, in contrast with the dark surface.

On opening the cylinder of an engine, a bright, mirror-like surface of the cylinder walls indicates poor lubrication. Many engineers believe that a bright, highly polished cylinder is an evidence of good lubrication, but it really is a proof of high frictional wear.

EFFECT OF OIL IN EXHAUST STEAM FOR HEATING.—The main difficulty with using exhaust steam direct from the engines and pumps for the heating mains is, that the oil carried over will form a coating on the inside of the piping, radiators and heating coils, and this coating of oil, which incidentally is very difficult to remove, greatly reduces the effectiveness of the heating surface, as an oil film is extremely non-heat conducting.

A good oil separator of the receiver type is recommended to remove the oil from the steam before it enters the heating mains.

STEAM-CYLINDER LUBRICATION AND FREE FATTY ACIDS.—(Messrs. Wells and Southcombe, *Jour. Soc. Chemical Industry*. Vol. xxxix, No. 5, pp. 51T-60T), state as follows "In the case of a steam engine using saturated steam, when there is a tendency for condensation of water to occur in the cylinder and valves, it follows that the presence of a substance in the oil, which lowers the surface tension against water will in such circumstances assist in the formation of oil films, by enabling the oil to spread more readily or by overcoming the tendency of the water to wash the oil film off. * * * The phenomenon of emulsification is dependent upon the colloidal properties of the oil. * * * Consequently we would expect the oil containing the higher members of the fatty acid group to possess an emulsifying tendency." They also state that the use of fatty-oil compounds in steam-cylinder oils is a waste of material, and that equally good results were obtained on engines with Corliss valves up to over 3000 H. P., working at 160–170 pounds per square inch pressure, superheated up to 480°–500° F., and on horizontal engines with Corliss valves up to 750 H. P. up to 160 pounds pressure, without superheat, by replacing the fatty-oil compounds with small proportions of fatty acid. This is in accordance with their theory on which their "Germ process" is based; namely, that the lowering of interfacial tension against water in the case of fatty oils was due to their slight content of free fatty acids, and that the sticky glycerides are unnecessary and wasteful. See index for fatty oils.

OIL CONSUMPTION IN STEAM CYLINDERS — Hilliger (*Zeitschrift des Verines deutscher Ingenieure,* 1918, Nos. 14, 15, 16, through Dingler's *Polytechnisches Journal,* Vol. 333, No. 14, July 13, 1918, pp. 122–124): Schmid gives the following formula for the hourly consumption of cylinder oil in grams in engines that are properly cared for:

$L = 1.6\, D_n s n$ Where D_n = the diameter of the low-pressure cylinder in metres,
s = the stroke in metres,
n = the R. P. M.

Weiss gives the following formula for the same conditions:

$L = 2D_h n$ Where D_h = the diameter of the high-pressure cylinder.

NOTE. One metre equals 39.37 inches. One gram equals 15.432 grains, or 1 ounce avoirdupois equals 28.35 grams.

Hilliger investigated these two equations, and when used for calculations for several engines he showed that the equations did not agree very closely, and apparently the equations as given above do not give the correct minimum values of oil consumption. He carried out tests with a view to determining the oil consumption of a steam engine as follows:

A locomobile made by the Wolf Company, of Magdeburg, with the cylinders lubricated by a pressure pump, which delivered 12 grams of oil per hour to the cylinders at 230 R. P. M. of the engine, was used. The cylinders were 130 mm. (5.1 inches) diameter and 260 mm. (10.2 inches) stroke. In making the tests, the cylinder received a definite amount of oil, and the lubrication was then stopped and the variation of mechanical efficiency with time was determined. The mechanical efficiency was determined with precision, in order to indicate the quality of the cylinder lubrication. The effective output of the locomobile was determined with a belt-driven, direct-current generator. The indicated output of the engine was determined from the equation:

$N_i = 0.015\, p_m n$ Where p_m = the average indicated pressure in atmospheres

In the test, with the boiler pressure maintained at 11.8 atmospheres, the electrical output was adjusted so that all tests were run at a constant speed of 230 R. P. M.

In this way the indicated output was maintained the same in all tests, and the effective output could then be calculated from the equation:

$$N_e = \frac{\text{voltage} \times \text{current}}{736\, E_e B_e}$$

Where E_e = the electrical efficiency of the generator.
B_e = the efficiency of the belt drive, which may be taken as 0.95.
N_e = effective output.

The mechanical efficiency is then:

$$E_m = \frac{N_e}{N_i}$$

The following table gives the physical characteristics of the three oils used in the tests by Hilliger:

Type	Specific Weight, Kg., Per Litre	Flash Centigrade	Engler Vis. at 100° Centigrade	Freezing Point Centigrade
American superheat steam oil	0.900	300	4.5	0
German superheat steam oil.	0.955	270	3.5	25
German oil	0.965	235	6.5	10

Note.—See conversion tables other section of book, for changing to American or English units.

The curve shown in Fig. 9 Sec. 10nn, shows the results obtained when German superheated steam oil was used with saturated steam. The regular lubrication curve of efficiency runs about 95 per cent., while with the

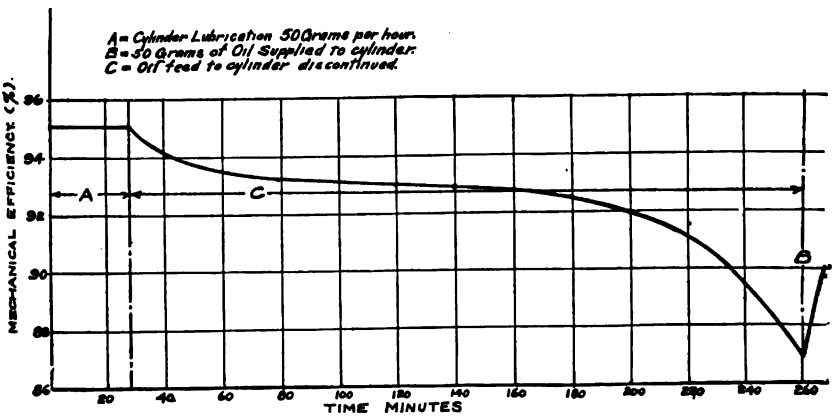

Fig. 9. Sec. 10*nn*.—Curve of mechanical efficiency and varying oil supply. Saturated steam. (Curve replotted from Hilliger.)

supply of oil discontinued the curve stays for a while at 95 per cent., and then begins to fall off rapidly. When the efficiency has fallen off 5 per cent. to 6 per cent., .50 grams (1.75 ounces) of oil were forced into the cylinder, which produced a considerable improvement in the mechanical efficiency.

The curve shown in Fig. 10, Sec. 10nn, shows the results of the tests when the German superheat steam cylinder oil was used with superheat steam. As shown, the efficiency did not fall off during the time that oil was fed regularly to the cylinders, but fell off rapidly when the supply was stopped, though not as rapidly as in the case of the saturated steam curve.

The curve in Fig. 11, Sec. 10nn, shows the efficiency curve obtained with variable oil feed and superheated steam, in order to determine the minimum amount of oil with which the cylinder of the engine can be uniformly operated, which may be defined as the minimum amount of oil with which the mechanical efficiency can be maintained at its highest

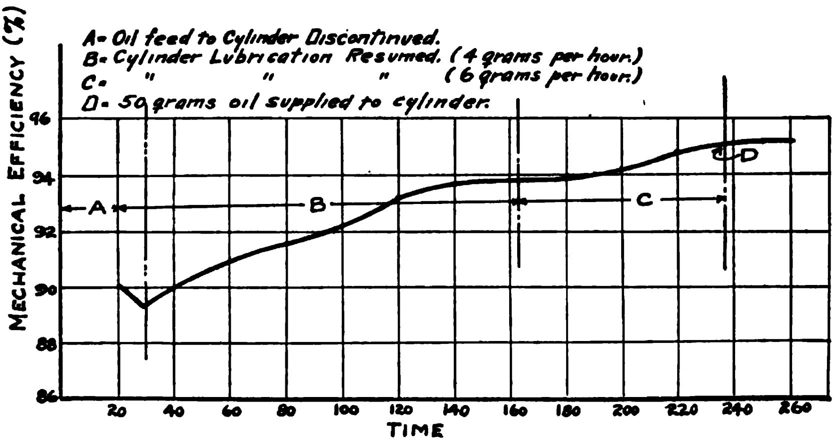

FIG. 10. SEC. 10nn.—Efficiency with variable oil feed. Superheated steam. (Replotted from Hilliger.)

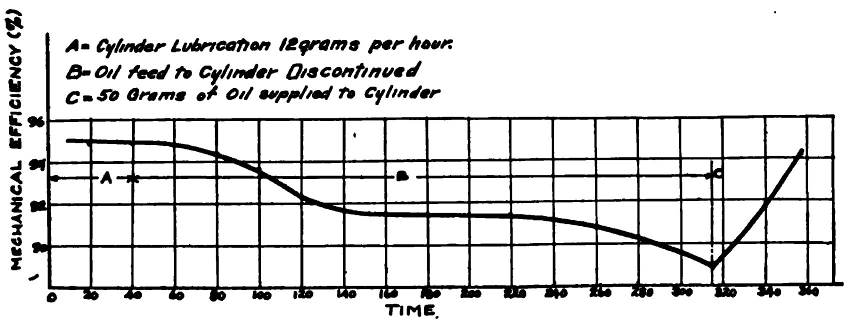

FIG. 11. SEC. 10nn.—Mechanical efficiency with variation in oil supply. Superheated steam. (Curve replotted from Hilliger.)

point. The reciprocal values of the amount of oil necessary to maintain efficient lubrication may be considered as index figures for the oils.

The curve shown in Fig. 12, Sec. 10nn, shows the manner in which the specific oil consumption varies with the indicated output. These values were derived from marine engines of similar construction. It will be noticed from the curve, that with increase in output the specific oil consumption decreases very rapidly, but at high points there is no longer

any noticeable decrease. In the total oil consumption, the oil required for lubrication of the auxiliary engines amounting to 8 per cent. to 10 per cent. of the total consumption has been taken into consideration.

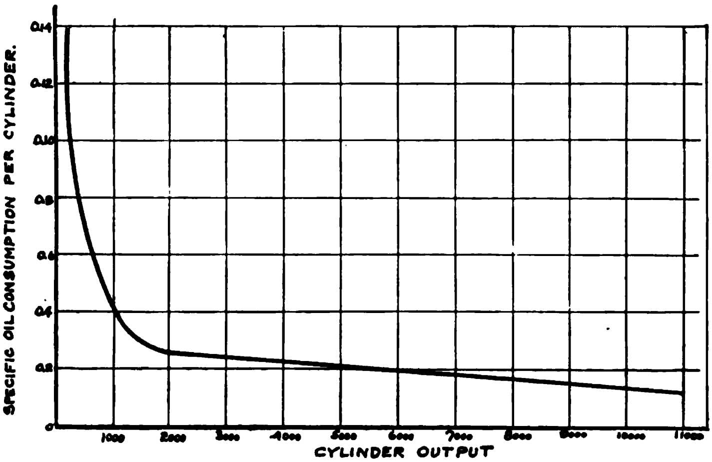

FIG. 12. SEC. 10nn.—Specific oil consumption and indicated power output. Marine engines. (Replotted from Hilliger's tests.)

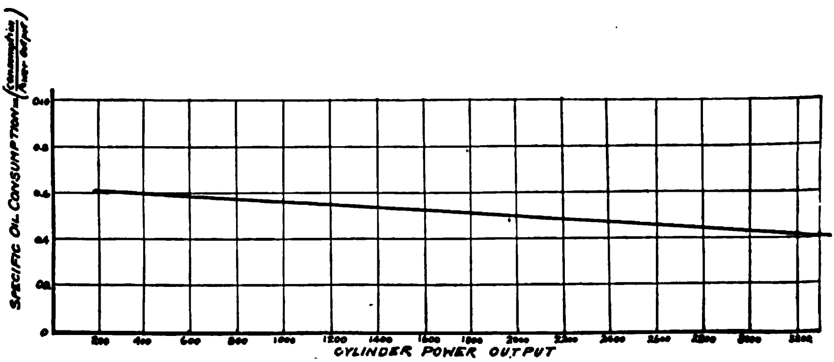

FIG. 13. SEC. 10nn.—Specific oil consumption and indicated power output. Horizontal engines, Stationary type. (Replotted after Hilliger).

Stationary engines of the vertical type show a higher oil consumption than marine engines. The straight-flow engines show a peculiar behavior, in that the specific oil consumption decreases with the increase of output along an approximately straight line; at the same time they have a very high general oil consumption, due, apparently, to the large piston surface and to the arrangement of the exhaust slots. The piston, in passing over

the exhaust slots, scatters through them a certain amount of oil, which in this manner is lost.

The curve shown in Fig. 13, Sec. 10nn, is intended to give an idea as to values of oil consumption found with horizontal stationary engines. It is difficult to establish a definite law for these engines, because of the great variety of types. These figures give the total oil consumption; that is, the oil which is used for lubrication of stuffing boxes on piston rods, valve rods and connecting rods.

NOTES ON CYLINDER LUBRICATION

CYLINDER OIL IN THE BOILER FEED.—Mineral oils, such as cylinder oils, that have passed out with the exhaust steam and been received by the hot well, may enter the boiler with the feed water.

Mineral oils form a brown, varnish-like coating when deposited on the interior surfaces of boiler plates. This coating is a poor conductor of heat, and, due to this fact, the water in the boiler cannot carry the heat away from the plate fast enough, and overheating of the plates may occur.

DRIP COCKS.—Care must be taken to see that the drip cocks of the engine cylinder are tightly closed after starting. If these cocks leak, even a very little, practically no oil will be distributed under the valve to lubricate the seat, and the result will be a "chattering" of the eccentric and sticking of the valve.

EXCESSIVE CYLINDER AND VALVE FRICTION may be detected by a groaning in the cylinder, vibration in the valve rods, and by heating of the eccentric.

STEAM-CYLINDER DEPOSITS.—When trouble is experienced with cylinder deposits, first examine the separator drain pipe. Very often the cause of the trouble will be found to be a clogged trap and pipe.

Often the piston rings have been set too tight, and, as a result, they have scraped into the soft iron of the cylinder. These iron scrapings combine with the oil, due to the adhesive attraction between the oil and iron, and form a heavy deposit.

The usual analysis of deposits from steam cylinders will show the presence of iron. Engineers usually refer to such iron as being the result of metallic wear, due to using a poor lubricant. However, many of these deposits are found in those parts of the cylinder and valve chest where no metallic wear could have produced iron scrapings.

Most steam cylinder deposits consist of magnesium, sodium, etc., all of which have been brought over by the steam from the boiler. When combined with the oil in the cylinder, with a little iron rust added, these substances form the majority of the cylinder deposits that are usually unjustly blamed upon the cylinder oil.

A typical cylinder deposit would analyze as follows:

Silica, magnesium, or earthy matter (mud)	40
Petroleum oil, with a small amount of saponifiable matter	35
Oxide of iron	20
Carbon	5
	100

PRIMING OF BOILERS.—The priming of boilers, with the resulting carrying over of particles of water mixed with solids, is one of the chief causes of cylinder deposits.

To illustrate the large amount of solids that may enter the cylinder by means of the steam, the following data are given: If a 100-H. P. boiler, evaporating 3000 pounds of water per hour, is operated with water containing 51.42 parts of solids to 100,000 parts of water, and the boiler is not cleaned out, at the end of a 10-hour day, 15.42 pounds of solids will have been liberated.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

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(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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A large percentage of these solids will float upon the surface of the water in the boiler, and if there is any excessive forcing or slackening of the fires and priming should occur, it can be easily seen there is a strong possibility of a cylinder deposit being formed, unless the separator is very efficient.

EFFECT OF BOILER COMPOUNDS ON CYLINDER LUBRICATION.—Boiler compounds usually consist of soda-ash, potash, caustic soda, or other substances of a similar nature, which have a very destructive effect upon cylinder lubrication if they are carried over by the steam to the cylinder.

Very often a complaint from an engineer regarding his cylinder oil, or particularly crank-case oil for vertical steam engines, may be traced to the excessive use of the above-mentioned compounds in the steam boiler.

These compounds may have been carried over to the cylinder, causing thickening of the oil, and may also have leaked out past the stuffing box to the crank-case, with the resulting formation of an emulsion.

NOTE. See index for physical tests of various cylinder stocks.

SECTION 10pp

STEEL MILLS

ROLLING MILLS AND THEIR LUBRICATION

ROLLING MILLS.—The production of rolled shapes of iron and steel is carried out in "rolling mills."

A "rolling mill" is composed of a train of "rolls," which are in turn composed of "roll stands." A "roll stand" consists of at least two rolls set between and carried by "housings." The rolls are made of chilled iron or steel, and are cylindrical. They are set one above the other, with their axes parallel and held in housings, so that there is a fixed space between them.

ROLL DRIVE.—The rolls are driven by motors or steam engines, through transmission gears, so connected that the rolls rotate in opposite directions. The gears are connected to the rolls and to the motive power by means of "spindles," which are short shafts connected by "coupling boxes."

ROLL NECKS.—The rolls are provided with journals, or "necks," as they are called. These "necks" are nearly as large as the rolls themselves.

ROLLING PROCESSES.—Iron and steel are rolled at a temperature that is high enough to soften and render the metal pliable. The rolling operation consists in passing the tough, pliable material between the rolls, and as the thickness of the material is greater than the space between the rolls, the result produced is compression and elongation.

ROLL SCREWS.—On the tops of the necks of the rolls are placed bearings, on which rest the ends of the roll screws, which are used to bring the rolls closer together, or further apart, as desired.

ROLL PRESSURES.—When a piece of steel or iron is being rolled, the pressure on the bearings and necks is tremendous, and good lubrication is, therefore, necessary.

TYPES OF MILLS.—There are two types of rolling mills; namely, "Reversing" and "Non-reversing" mills.

"Reversing mills" have only two rolls—set one above the other. The mill is stopped after each "pass" and the power is reversed, so that the material may be rolled back in the opposite direction. The engines of these mills are very heavy and powerful, because no fly-wheel can be used to store up the energy necessary to overcome the overloads.

The "continuous," or "non-reversing," type of mill has three rolls, arranged one above the other. The material is passed between lower and middle rolls in one direction, returning between upper and middle rolls.

"Billet mills," "sheet bar mills," "rod and wire mills," "hoop" and "cotton tie" mills, and 20- to 32-inch sheet mills, are usually built of the continuous type, which has a number of stands of two rolls arranged one behind the other, and which may or may not be driven at increasing speeds, progressively.

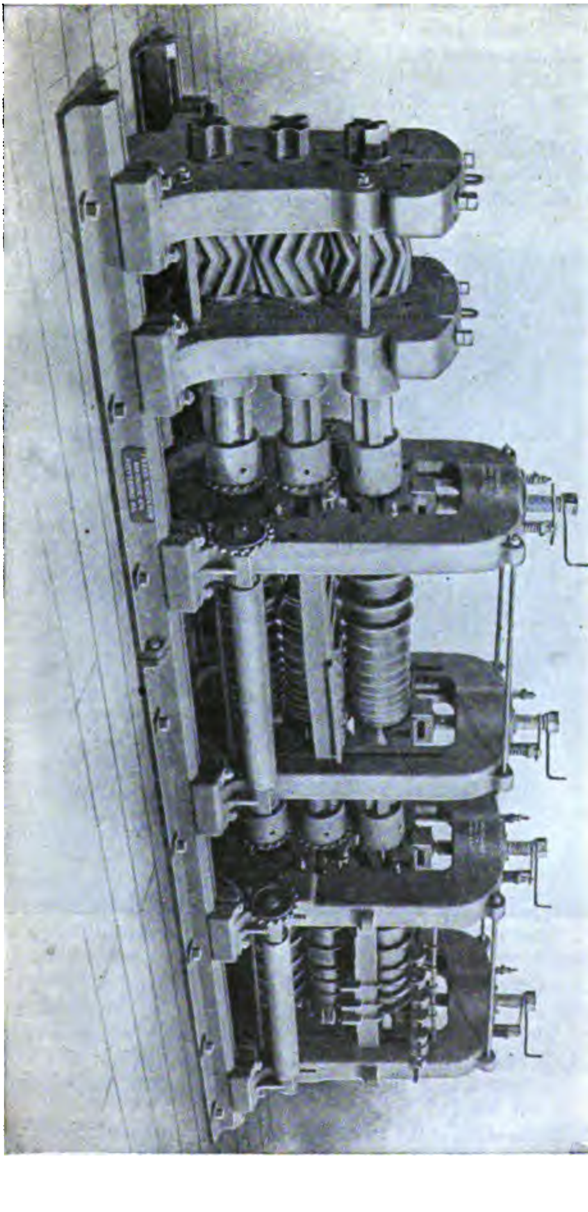


FIG. 1. SEC. 10pp.—18-inch bar mill.

Rolling mills are distinguished by the name of the material which they produce. When referred to by their size or rating, the dimension refers to the diameters of the rolls for all types except plate rolls, which are rated by the maximum width that they can roll.

A typical 18-inch bar mill, as manufactured by the United Engineering and Foundry Company, of Pittsburgh, is shown in Fig. 1, Sec. 10pp.

COLD ROLLS.—Rolls for rolling rails, bars, rods, structural shapes, etc., are fitted with water pipes, so that streams of water can be kept running over the roll necks to prevent overheating.

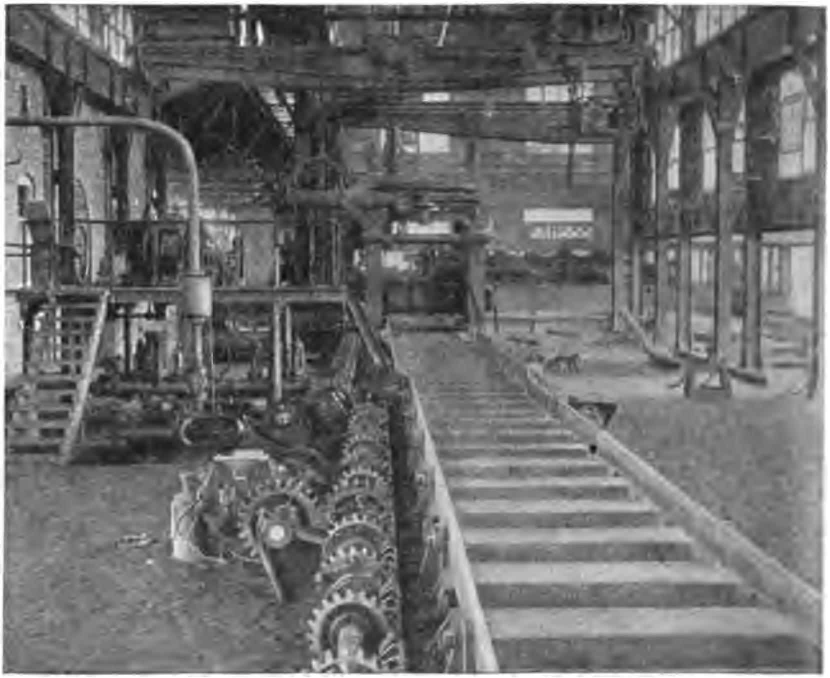


FIG. 2. SEC. 10*pp*.—38-inch blooming mill and tables.

Cold-neck grease is used for the lubrication of cold rolls. This grease is composed largely of suet or tallow, either plain, or mixed with a petroleum grease. The mixed greases are called "tallow compounds."

Cold-neck grease is usually packed directly against the roll necks. It is usually contained in a burlap bag and fed gradually by melting, to the surfaces of the necks.

HOT ROLLS.—Rolls for making sheet steel, tin plate, etc., are called hot rolls. No water can be used to cool the necks of these rolls, due to the nature of the work being done, and, as a consequence, they run at very high temperatures.

Hot-neck rolls are lubricated with a petroleum residuum, stearin pitch or wool pitch, thickened with resin, talc, lime graphite, or other substances. This grease is of so dense a nature that it must be melted by the application of heat before it can be swabbed on the roll necks. Grease for this purpose is called "hot-neck grease." Hot-neck grease has very high adhesive properties. After using, it is usually collected, and after remelting and settling to remove the dirt, it can be used again.

DRIVE GEARS.—The gears in rolling mills are large and should be lubricated with a medium-bodied "pinion grease." This grease is made of a petroleum residue combined with pine tar.

The small, fast-running gears should be lubricated with a dark gear grease. Usually a brush is used to apply this grease.

Table-roll journals, electric cranes, and other similar machinery should be lubricated with a black oil. Surfaces that require lubrication, and that are near to soaking pits and hot metal, should be lubricated with a very thin pinion grease, or with a black oil.

Dust and mill scale cause the worst trouble in the lubrication of rolling mills, and all bearings should be kept covered.

TYPICAL ROLLING-MILL MACHINERY.—The following mill installations of machinery are shown, for the purpose of demonstrating the lubricating conditions to be met with in this class of operations.

Fig. 2, Sec. 10pp, shows a 38-inch Blooming Mill and Tables at the Sharon Works, Carnegie Steel Company.

Fig. 3, Sec. 10pp, shows an 84-inch Plate Mill at the La Belle Iron Works, Steubenville, Ohio.

Fig. 4, Sec. 10pp, shows a 28-inch Merchant Mill in the Duquesne works of the Carnegie Steel Company.

Fig. 5, Sec. 10pp, gives a view of two Morgan Continuous Mills at the Youngstown Sheet and Tube Company, Youngstown, Ohio.

Fig. 6, Sec. 10pp, shows a typical 20-inch Merchant Mill as installed at the Singer Manufacturing Company, Elizabethport, New Jersey.

Fig. 7, Sec. 10pp, shows the construction of a 100-inch Plate Straightening Machine and 84-inch Plate Mill at the La Belle Iron Company, Steubenville, Ohio.

The above machinery was manufactured by the United Engineering and Foundry Company, of Pittsburgh, Pa.

OTHER OILS.—"Torch oil" is used by rolling-mill employees for their hand torches. This oil should have a good flash test and burn without excessive smoking. A very light-bodied paraffin oil may be used.

The usual rolling-mill engines operate under very dusty, dirty conditions. * The bearings are mostly cup fed and should be supplied with an engine oil of about 250 Vis. at 100° Fahr. (P. B.), or 350 Vis. at 100° Fahr. (A. B.). The oil should have a good cold test. The cylinders of these engines are usually supplied with fairly wet steam, as the steam piping and separators are often in poor condition. A low viscosity, well compounded cylinder oil is recommended.

LUBRICATING DATA.—Roll bearings are subjected to tremendous pressures, and are also in constant contact with water, used for cooling, with steam used for removing the scale from the steel, and, in some cases,

* Grease lubrication will be found to show good results on these bearings.

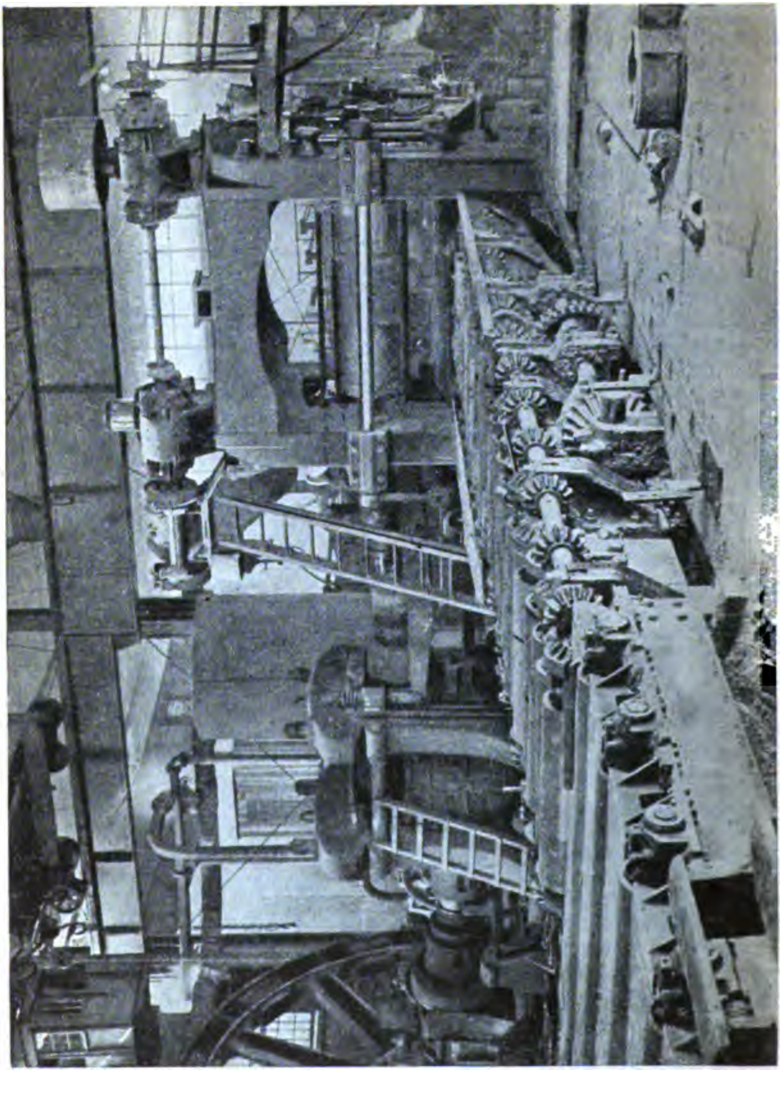


FIG. 3. SEC. 10pp.—84-inch plate mill.

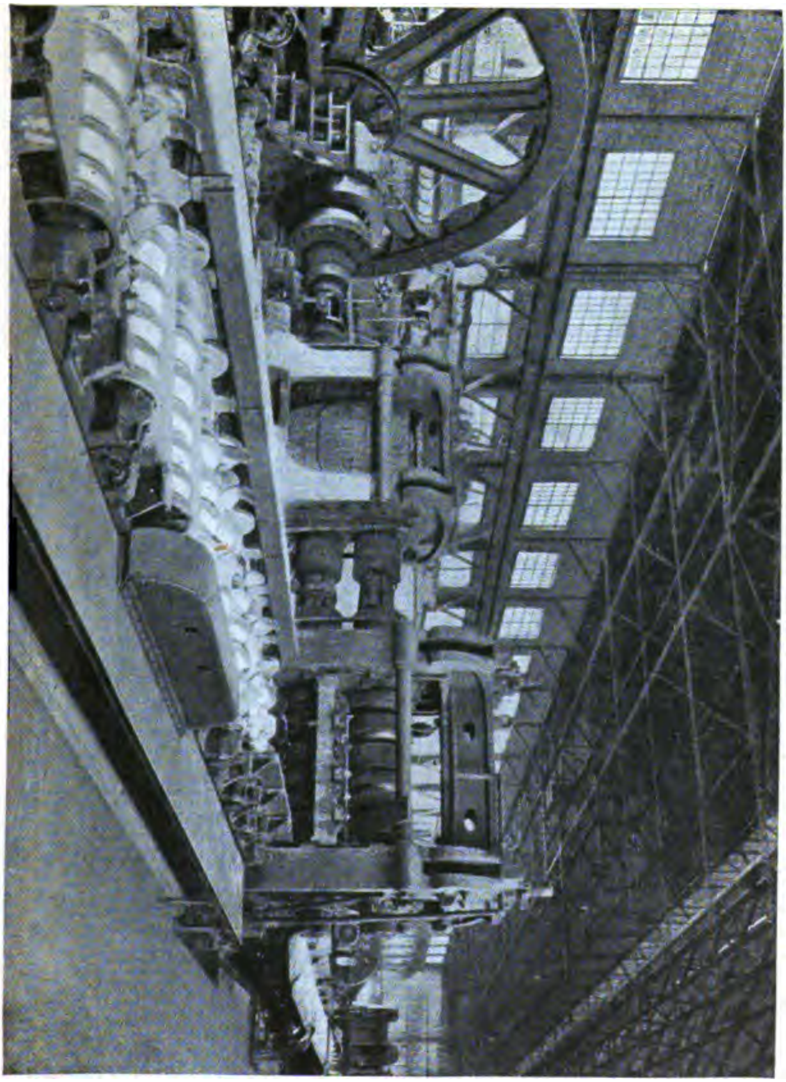


FIG. 4. SEC. 10pp.—28-inch Merchant mill.

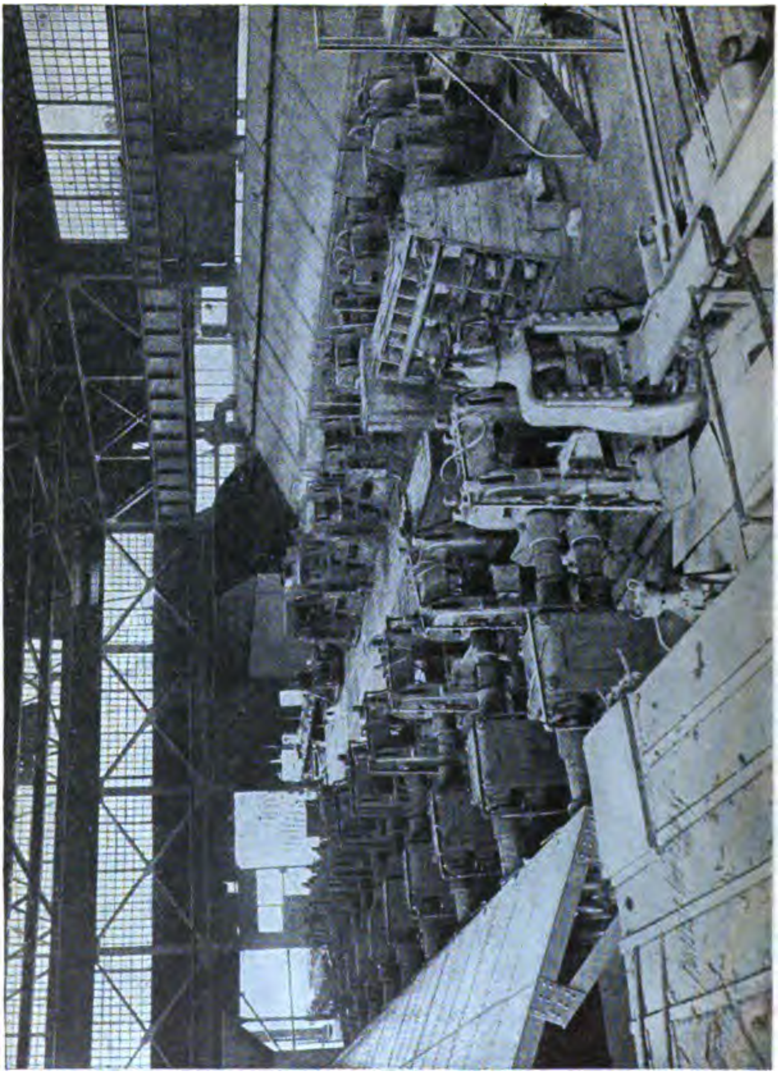


Fig. 5. Sec. 10pp.—View of two Morgan continuous mills.

with salt used for the same purpose. The hot steel during the rolling process passes within a very few inches of the roll bearings, exposing them to extreme heat. These conditions are factors affecting the lubrication of these bearings, and at the best they are very poorly lubricated. The "mill tables" have both journals and gears to lubricate. They are usually lubricated by hand and should be given plenty of black oil. Some of the heaviest types of mills are equipped with a continuous oiling system,

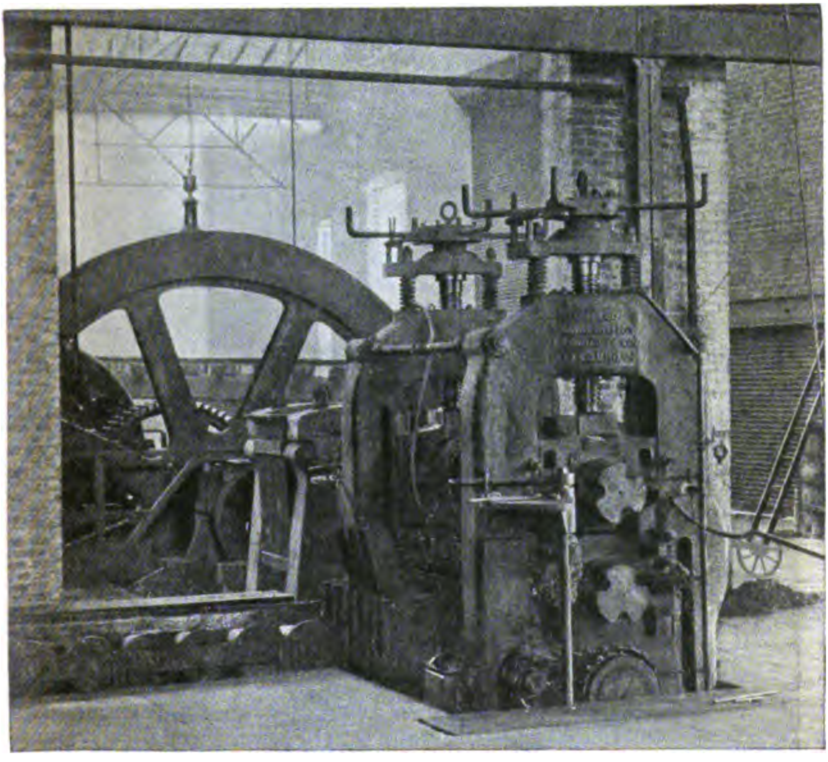


FIG. 6. SEC. 10pp.—Typical 20-inch Merchant mill. (Motor driven.)

for which an engine oil of 275 to 325 Vis. at 100° F. (P. B.), or 400 to 450 Vis. at 100° F. (A. B.), may be used.

The bearings of the "hot saw," which is used for cutting semi-finished steel, and those of the "cold saw," which is used for cutting the finished product, are examples of high-speed bearings operating under heavy pressure. These bearings are often equipped with ring oilers, and should be treated as a motor bearing when selecting the oil.

Hydraulic pressure is used in large mills for adjusting the mill tables with three mill work, for operating hydraulic cranes, for feeding the hot

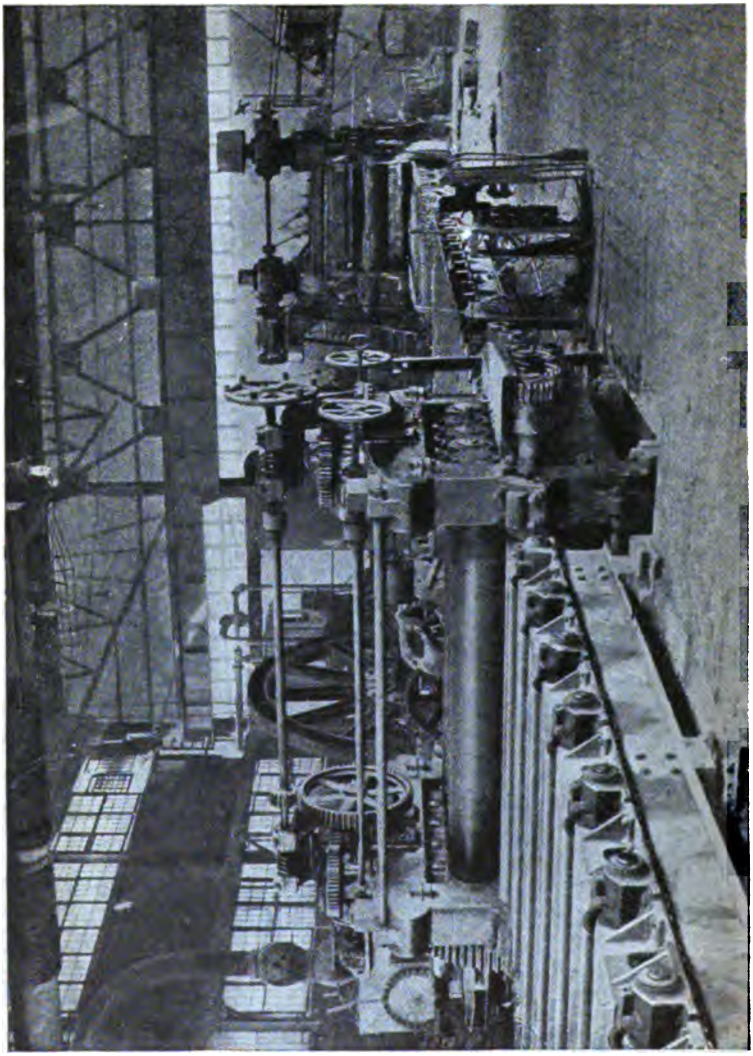
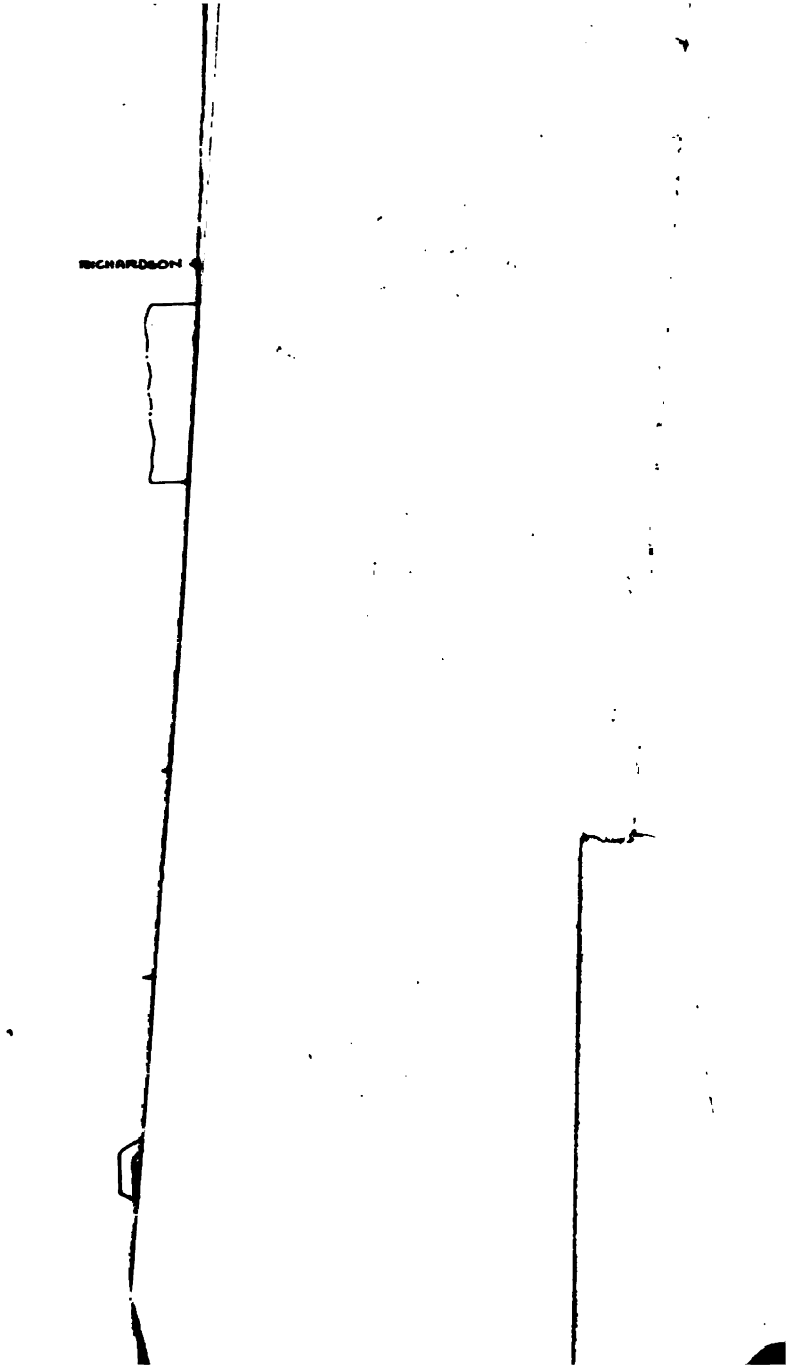


Fig. 7. Sec. 10pp.—100-inch plate straightening machine and 84-inch plate mill.


RICHARDSON

saw, for handling heavy ingots on the tables, and in some cases for operating large shears for shearing hot metal. It is also used in the armor-plate departments to operate the presses. The plungers, press internal parts, pump valves, etc., should be lubricated through the agency of the water used in the system, by mixing with it a soluble oil or compound, and depending upon the water to carry this lubricant to, and deposit it upon, the various surfaces requiring lubrication. A typical compound used for this purpose consisted of an alkali soap, mineral oil and fixed saponifiable oils and water. The percentages were about as follows: 20 per cent. to 25 per cent. of water, about 20 per cent. alkali soap and about 40 per cent. mineral oil.

Fig. 8, Sec. 10pp, shows an oiling system for mill lubrication from a central storage.

SECTION 10qq

SUGAR HOUSE MACHINERY

SUGAR-HOUSE MACHINERY.—Equipment: The main equipment of a sugar house is:

(*a*) Prime mover (Corliss engines usually).
(*b*) Driving rollers and crushers (operated by numerous gears).
(*c*) "Effect pans."
(*d*) Vacuum pumps.
(*e*) Air compressors.
(*f*) Syrup pumps.
(*g*) Filter presses.
(*h*) Juice pumps.
(*i*) Circulating pumps.

The average cost of sugar-house machinery is approximately $250 per ton of cane crushed per 24 hours. Under the old methods, the yield was approximately 50 pounds of sugar per ton of cane, or 2 1/2 per cent. Under the modern methods this is much better, being about 160 pounds of sugar, or 8 per cent.

OPERATING CONDITIONS.—The season for operating these plants is short and plants must be operated continuously.

Roller and crusher journals average 15 to 20 inches in diameter and from 15 to 25 inches in length. The pressure (hydraulic) on these journals is very high. An adhesive, flowing lubricant, such as a light-bodied gear lubricant, or a pinion grease, is best suited for their lubrication. The "centrifugals" demand good lubrication. In the past sperm oil and lard oil have been largely used for this purpose, and in some cases are still being used, but an oil of about 145 Vis. Say. at 100° F. (P. B.), or 160 (A. B.), will give good results.

A soluble hydraulic lubricant is also used.

For the gears, a petroleum-pitch gear compound of medium consistency is recommended.

For the steam cylinders and air cylinders, follow the suggestions outlined in the chapters on those subjects.

OILING SYSTEMS, SUGAR-CANE MILLS.—Fig. 1, Sec. 10qq, shows a method for oil distribution on standard sugar-cane mill bearings. Fig. 2, Sec. 10qq, shows a forced-feed oiling system for sugar-mill crusher-roll bearings. Fig. 3, Sec. 10qq, shows a gravity oiling system for sugar-mill machinery.

FORM 1 HP

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RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

.SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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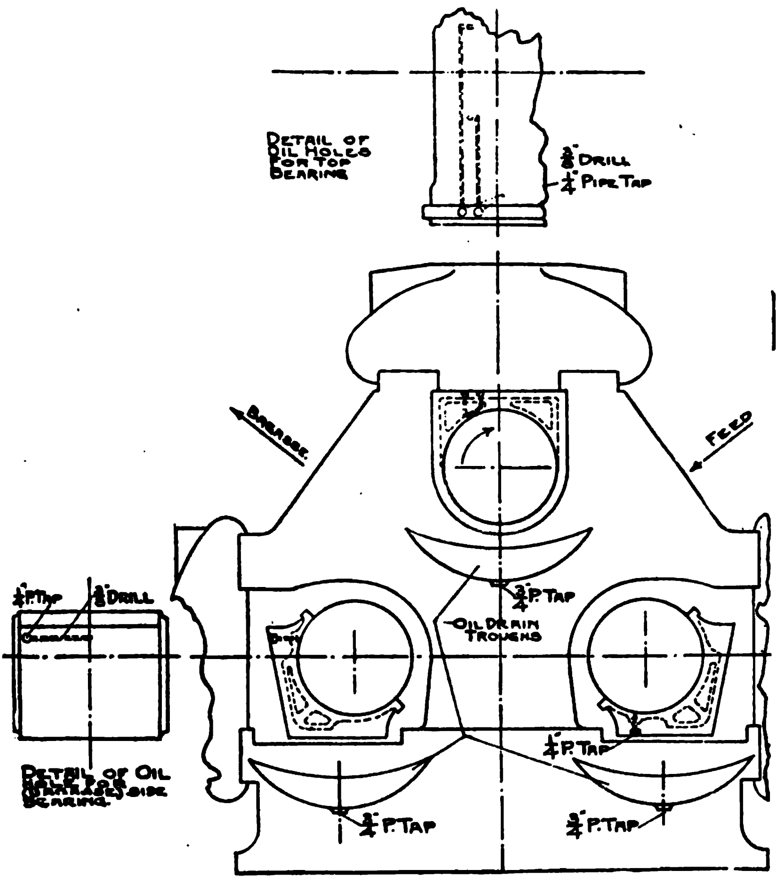


FIG. 1. SEC. 10qq.—Oil distribution standard sugar cane mill bearing.

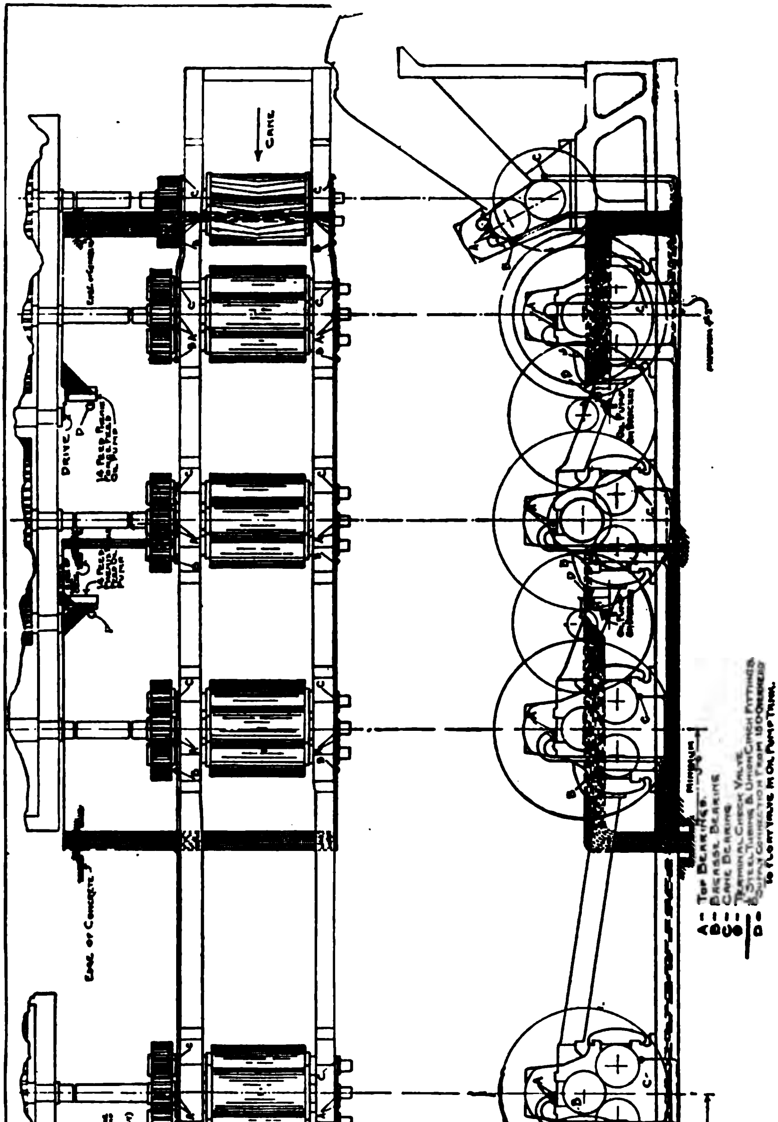
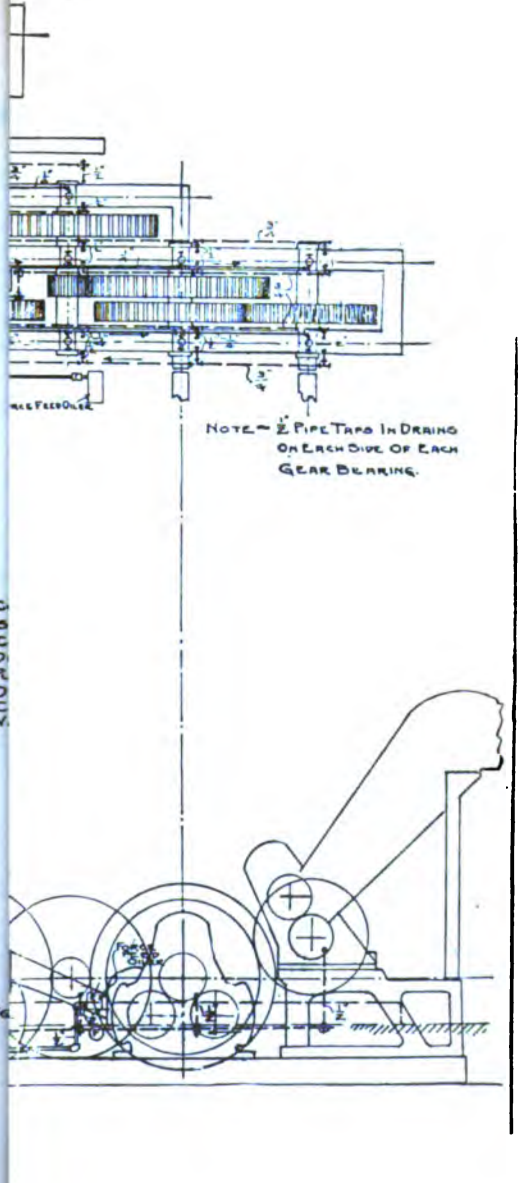


FIG. 2. SEC. 10qq.—Forced feed oiling system for sugar mill machinery.



FORCE FEED OILER
NOTE — 1/2" PIPE TAPS IN DRAINS ON EACH SIDE OF EACH GEAR BEARING.
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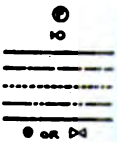

FORM 1 HP

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RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

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SECTION 10rr

TEXTILE OPERATIONS

TEXTILE MILLS.—The consumption of power in a textile mill is not divided among a few machines, but is distributed among possibly thousands of spindles, light high-speed machinery, long lines of shafting, many looms, and other machines. The unit friction in any one of the bearings of this light, high-speed machinery may be very small, but it is repeated in many thousands of these bearings, and as a result, the cost of power is a heavy fixed expense in any textile mill.

COST OF POWER.—The average cost of power, to manufacture a textile product, has been given by several authorities to average 10 per cent. of the mill selling price of the finished product.

A power saving of 25 per cent. will thus enable the manufacturer to cut the selling price of his product 2.5 per cent., enabling him to secure additional business in competitive selling.

Ring oilers, babbitted bearings, and self-aligning ball bearings have greatly reduced the former heavy friction loads of the transmission shafting in textile mills, and the lubricating engineer will find the most productive field for his efforts in the improvements resulting from efficient lubrication of the individual machines and spindles.

TEXTILE INDUSTRY IN U. S.—The textile industry leads all industries in number of plants with yearly production valued at $1,000,000 or more. It uses about 3,000,000 horse-power, over one-eighth of the total power used in American plants. Of a total of 7884 textile mills in the United States, about 51 per cent., including silk mills, knitting mills, cotton and woolen mills, are in the Middle Atlantic States; 21 per cent., chiefly cotton and woolen, are in New England States, and 17 per cent., chiefly cotton and hosiery, are located in Southern States. About 645 mills are in the Middle West, and about 125 in the Western States.

The textile industry uses an estimated 12 1/2 per cent. of all coal burned in industrial plants. It is estimated that there are over 1500 textile plants using over 1000 horse-power and up, and over 2000 using more than 100 horse-power and less than 1000 horse-power.

LUBRICATION

LUBRICATION FACTORS IN TEXTILE MILLS.—There are seven important factors:

1. Rate of production.
2. Stained goods.
3. Power cost.
4. Mill conditions.
5. Power transmission losses.
6. Replacement costs.
7. Repair-time costs.

"*Rate of Production*": High speed means high production. It is necessary to have efficient lubrication if machinery is to run at high speeds for long periods of time. The lubricant must be of a character to provide lubrication for the longest possible time without reoiling.

"*Stained Goods*": There is a substantial fixed expense in all mills, based on the stained-goods evil. There never has been and probably never will be a stainless lubricant. If a lubricant is thrown from a bearing, it carries with it more or less metallic wear, which cannot be washed out of the fabric.

The only method that will insure a reduction in the oil-stain evil is to use a lubricant that will not throw, drip or climb. The lubricant must meet the requirements of high speeds, as to feed, and yet possess sufficient adhesiveness to resist throwing.

"*Power Costs*": A well-known textile manufacturer estimates that the power cost of a textile mill averages about 10 per cent. of the mill selling price. Thus, if the power loss due to unnecessary friction can be reduced 25 per cent., there will be an added profit to the mill of 2 1/2 per cent.

"*Mill Conditions*": Mill operators, as all other workers, can do better work under clean, safe, sanitary conditions. The use of a poor lubricant. or excessive, dripping, spattering lubricants, will not only increase the fire risk and increase the waste of lubricants, but the dirty oil-soaked floors and equipment will reduce the working efficiency of the workers.

"*Power Transmission Losses*": There are a multitude of bearings in the average textile mill. The power lost in line shafting, due to poor alignment and faulty lubrication, is enormous. Ball and roller bearings are recommended for shaft hangers, post hangers, and pillow blocks. (See line shafting in index.)

"*Replacement Costs and Repair-Time Losses*": Replacement costs and repair-time losses must be added onto the general cost of manufacture in making up the fixed charges.

The majority of replacement costs in textile mills are traceable to poor lubrication. The finest machinery in the world breaks down under imperfect lubrication.

The costs of repair time are directly evident.

When it is considered that faulty lubrication for a short time may result in the shut-down of a section of the mill and necessitate a costly replacement, the value of lubrication under scientific conditions is evident.

The life of a machine and the value of its productive power is de-

pendent upon the life of its component parts, and this factor is dependent upon lubrication.

POWER REQUIRED BY VARIOUS TEXTILE PLANT MACHINERY.—The following table gives the average power required by various textile machinery under normal conditions of good lubrication and other factors:

POWER REQUIRED BY VARIOUS TEXTILE MACHINERY UNDER AVERAGE CONDITIONS

Willow	7 H. P.
Bale breaker	5 H. P.
Single-beater picker	4 H. P.
Double-beater picker	8 H. P.
Self-feeder	1 1/2 H. P.
Roller card	2 to 3 H. P.
Revolving flat card	3/4 to 1 1/2 H. P.
Sliver lap machine	1/2 H. P.
Ribbon lap machine	1 H. P.
Comber, 8 heads	1/2 H. P.
Drawing frame, per delivery	1/4 H. P.
Slubber fly frame	48 spindles per H. P.
Intermediate fly frame	60 spindles per H. P.
Fine fly frame	90 spindles per H. P.
Jack fly frame	110 spindles per H. P.
Spinning frame, medium gravity spindle, 8500 R. P. M.	55 spindles per H. P.
Spinning frame, standard gravity spindle, 9700 R. P. M.	65 spindles per H. P.
Spooler	200 spindles per H. P.
Mule, 9600 R. P. M.	130 spindles per H. P.
Quiller	190 spindles per H. P.
Twister, spindle, 6500 R. P. M.	40 spindles per H. P.
Warper	1/6 to 1/4 H. P.
Slasher	1 1/2 to 2 H. P.
Loom	1/6 to 1/3 H. P.
Wide loom	1 H. P.
Yarn reel, 50 spindles	1/6 H. P.
Brusher and shearer	3 H. P.
Folder	1/8 H. P.

DEPRECIATION OF MACHINERY.—Depreciation of cost of machinery means, dividing the original cost of the machine into an equal number of parts, and charging up one of these parts each year as an expense, until the entire cost of the machinery has been charged, into the cost of manufacturing the product of the machine. Thus, when the output of the machine over that period of time has been sold, the original cost of the machine has been recovered and the machine can be replaced.

From early times 10 per cent. on machinery and 2 per cent. on buildings has been the usual amount adopted as annual depreciation. There is no set rule as to whether the 10 per cent. is to be figured on the original cost of the machine or on a diminishing balance.

The life of a machine depends upon the treatment it receives. The factor of lubrication is probably the most important in connection with depreciation. Of course, the machine may become obsolete, due to new improvements that may be perfected.

In an underwear mill, the carding machines might be allotted 50 years, the knitting machines 30 years, and the finishing machines 10 to 25 years. In hosiery mills, the knitting and looping machines may have a life of 15 to 20 years, the dyeing and drying machinery 10 to 50 years, and the finishing machinery 10 to 50 years.

If the machinery can be kept in good condition for a longer time, due to scientific lubrication, the depreciation cost will be smaller and the charge that must be made in the manufacturing cost will be thus decreased.

Depreciation is a strong argument for improved lubrication.

TEXTILE TERMS.—"Cut" is used in the Philadelphia district, and to some extent in other districts in the United States, for grading woolen yarns. The "lea" is used in linen. The "cut," "hank," or "lea" is 300 yards, and the number of such cuts, or leas, per pound is the number of the yarn. In linen, a "spindle" is 48 leas, or 14,400 yards. A "bundle" is 200 leas, or 60,000 yards.

In the French system of numbering, which is based upon the metric system, where 1 metre equals 39.37 inches, and 1 kilogram, or 1 kilo, equals 2.2047 pounds, the base used for numbering yarns is according to a thread of cotton, 1000 metres long weighing 500 grams, which is half a kilo, that is called No. 1. No. 2 equals 2000 metres weighing 500 grams. No. 3 equals 3000 metres weighing 500 grams, No. 4 equals 4000 metres weighing 500 grams, etc. This length of 1000 metres is termed a "hank," or "ecevau," and each hank is divided into 10 skeins, or "echevettes," of 100 metres each. These skeins are wrapped on a reel having a circumference of 1425 metres, making 70 revolutions. Thus the count indicates the number of hanks required to weigh 500 grams, whence the rule: Divide the metres reeled by twice the weight in grams, and the result is "counts," French. French counts can be reduced to English by multiplying the French yarn number by 1.18, which gives the result in English counts, or dividing the English counts by 1.18 to give the equivalent number of French counts.

COTTON GINNING MACHINERY

TYPES OF GINS.—The cotton gin must not only clean the cotton, but must do so without impairing the staple. The primary types of cotton gins are the single-breast or plain gin, and the double-breast or huller gin. The double-breast gin, or huller gin, differs from the plain gin in that it is designed to handle bolly or immature cotton. Besides the gin, a ginning plant generally has feeders, a pneumatic elevator, lint flues, condensers, a press, a seed-blowing system and the driving attachments from the engine.

The line of gins of the Continental Cotton Ginning Company includes the Munger, Winship, Pratt and Eagle Gins. Ring oilers are widely used on gins. Grease cups are also used.

Gins are made both with and without brushes, for removing the lint from the saw teeth.

The Lummus Cotton Gin Company give the following general specifications for bearing speeds:

LINE SHAFT SPEEDS

For one-story air blast, two-story air blast, one-story brush and two-story brush (if suspended idler, 275 R.P.M.) .... 425 R.P.M.
Two-story plantation .... 275 R.P.M.

STANDARD SAW AND BRUSH SPEEDS

Type of Gin.	Saws (R. P. M.)	Brush (R. P. M.)
For air blast plain, 10-inch saws	450	....
For air blast, 12-inch saws	425	....
For independent drive brush, plain, 10-inch saws	450	1700
For independent drive brush, 12-inch saws	425	....
For independent drive brush, double-rib huller ..	425	1700

COTTON AND SEED ELEVATORS.—There are two types for handling cotton from the carts to storage or to the gins, *viz.*: Pneumatic and belt. The belt type is widely used. For the seeds from the gins. screw conveyors are used. There are gears, fan bearings, and conveyor bearings to lubricate.

FEEDERS FOR GINS.—The main types are distributer-apron type, upright cleaner-feeder and basket-feeder types. There are gears and pulley bearings to lubricate.

TRAMPERS AND PRESSES.—These may be operated by screws. hydraulic or steam power. For hydraulic presses, a steam, compressed air or belt-driven pump is used. Screws, gears, hydraulic rams, chains, etc., are to be lubricated. Both oil cups and grease cups are used.

COTTON OPERATIONS.—In order that the industrial oil engineer may have an intelligent idea of the processes used in the manufacture of cotton yarns, the following brief outline is included in this chapter:

The cotton is taken from the "bale" and dried. It is then cleaned by passing through a series of "picker machines," named in order as follows: (*a*) Automatic Feeder, (*b*) Breaker Picker, (*c*) Intermediate Picker, and (*d*) Finisher Picker. These machines pull the matted wads of cotton to shreds and remove the dirt, sticks, stones, and seeds.

The cotton is now in the form of "batting" on the cylinders. It comes from the finishing pickers as "lap."

The "carders" comb the fibres parallel, by means of revolving cylinders, which are covered with a large number of wire teeth. These teeth are called "card clothing." Any "fine leaf," short fibres, etc., is removed by the carders.

The lap is now in the form of a "web" about a yard wide. This web is passed through small "eyes." These bring the lap into narrow bands, known as "card slivers." Sometimes, if a very fine, strong yarn is desired, it may be combed in addition to carding, but in most mills this process is passed over.

"By combing" is meant the removal of short fibres, known as "waste," so that only the longest and strongest fibres remain.

The "slivers" are now composed of fibres, and a slight pull will bring them straight, or parallel. The "drawing frame" is used for this purpose. It consists of a number of sets of rollers, the front roller having a faster speed than the rear rollers.

The "slivers" come from the drawing frame combined as one "sliver." The processes, through which the stock has now been passed. have been designed to arrange the fibres, clean them and make them uniform.

The "sliver" is now again drawn out by the "flyer frames," but in addition it also receives a slight twist. It passes through several of these frames, having the same general construction, but differing in size of the parts. The machines are called "slubbers," "intermediate," and "roving." Each machine draws and twists. The "intermediate" takes the very slightly twisted "rove" from the slubber and gives it more twist, and then passes it on to the "roving machine."

The "spinning process" consists in drawing out the cotton roving to the desired size and giving it some twist. There are two methods of spinning, known as "ring" and "mule."

The oldest method is "mule spinning," in which the spindles are mounted upon a "carriage," which is moved in and out with reference to the "rolls."

When the spindles are moving away, the stock is being delivered by the rolls, but at little slower rate than the travel of the carriage, so that there results a slight pull. At the same time a twist is given to the yarn, and when the end of the outward carriage travel is reached, the rolls are stopped and the yarn is wound on the spindles as the frame moves in.

"Ring spinning" differs from "mule spinning" in that the mule carriage is replaced by a ring. The ring is connected with a "twiller," which acts as a drag on the yarn. It is shaped like a letter D and made of flat steel wire.

COTTON MACHINERY LUBRICATION

OPENING AND MIXING MACHINERY—BALE BREAKERS.— These machines run at the driving-shaft speed, of about 450 R. P. M. They are used to open the stock. Generally about 4 1/2 to 5 H. P. is required to drive them.

For the gears of this machine use No. 2 or No. 3 cup grease, or a semi-fluid lubricant of seven-eighths consistency.

For the general lubrication use an oil of 250 Vis (P. B.), or 300 Vis. (A. B.), or a semi-fluid lubricant of one-half consistency of vaseline.

BREAKER LAPPERS.—Fig. 1, Sec. 10rr, shows a breaker lapper made by the Whitin Machine Works. This machine is used to clean the

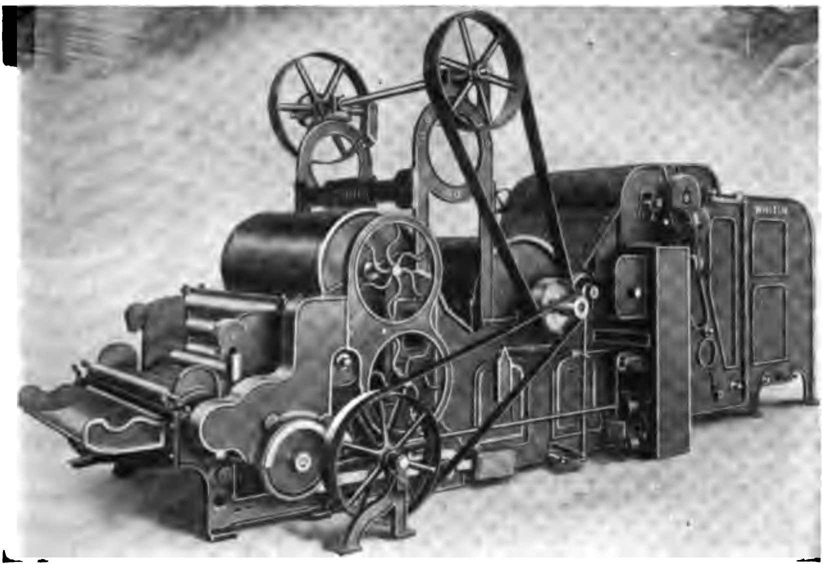

FIG. 1. SEC. 10rr.—Breaker lapper equipped with automatic feed and lapper.

raw stock and to convert it into "lap." It usually requires about 4 to 8 H. P. to drive. Its driving-shaft speed is about 430 to 440 R. P. M.

For the lubrication use recommendations of bale breaker.

"**FINISHING LAPPERS.**"—This machine is used on the better grades of cotton, to clean the stock better. It adds another process to the picking. They require about 4 to 5 H. P. to operate, and the driving-shaft speed is about 435 R. P. M. Use the same lubricating recommendations as above.

The " Evener Box " of a picker is a gear and worm running at about 1500 R. P. M. Usually it is equipped with an oil-tight case. A semi-fluid grease of about three-fourths consistency is recommended for lubrication, or a worm-gear lubricant.

Fig. 2, Sec. 10rr, shows a view of a motor-driven Kitson Machine Company's finisher picker.

Many modern cotton pickers and openers are equipped with ball bearings. In some cases, power savings of 3/4 H. P. have been obtained per beater.

Fig. 3, Sec. 10rr, shows a series of views of picker ball-bearing equipment. For the lubrication of these bearings, a strictly neutral grease of No. 1 consistency is recommended.

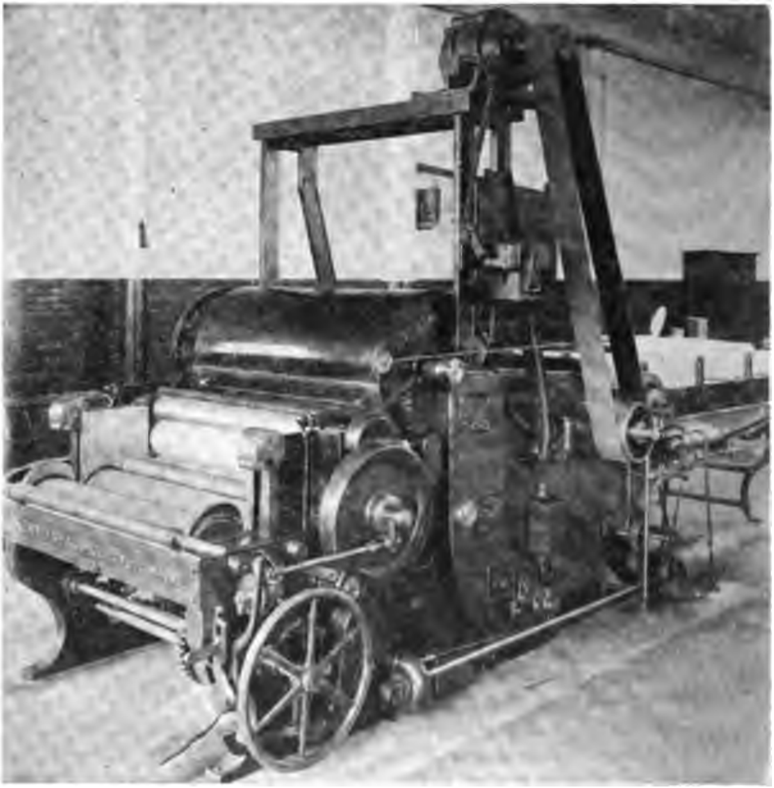

FIG. 2. SEC. 10*rr*.—Finishing lapper, motor driven.

CARDING.—One of the main points of the lubrication of the cards is the care that must be taken to prevent the lubricant getting onto the card clothing, and also the ease of starting the cards after a shutdown.

A revolving flat card requires about .85 H. P. for 36 grains (weight of one yard of "sliver"), producing 80 pounds per 10 hours at 165 R. P. M. of the cylinder. When producing 76 grains, at the rate of 220 pounds in 10 hours, about 1.75 H. P. is required.

Fig. 4, Sec. 10rr, shows a cotton card, equipped with ball bearings on the "main cylinder," "doffer cylinder," and "licker-in."

The "comb box" of the card, which actuates the doffer comb for taking off the lap, is an important point of lubrication. In the plain type

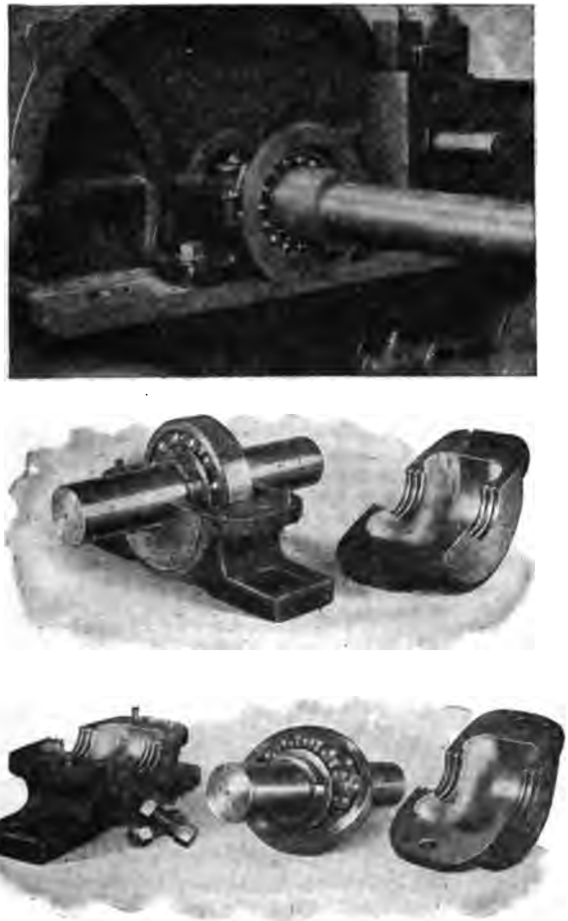

FIG. 3. SEC. 10*rr*.—S. K. F. ball-bearing beater box in place and knocked down.

of box, the combined rotating and sliding movements require a lubricant which is free flowing and yet has no tendency to creep or climb. A semi-fluid lubricant of three-fourths consistency is recommended.

Fig. 5, Sec. 10rr, shows a ball-bearing comb box, and also the comb box knocked down, as made by the Hubbard Machine Co.

If the eccentric of the comb box revolves, so that there is play between the eccentric and the fork, a vibration will be set up, loosening the comb-posts, that hold the blade of the comb. As a result, the doffer comb will be allowed to come into contact with the wire on the doffer and the teeth on the comb.

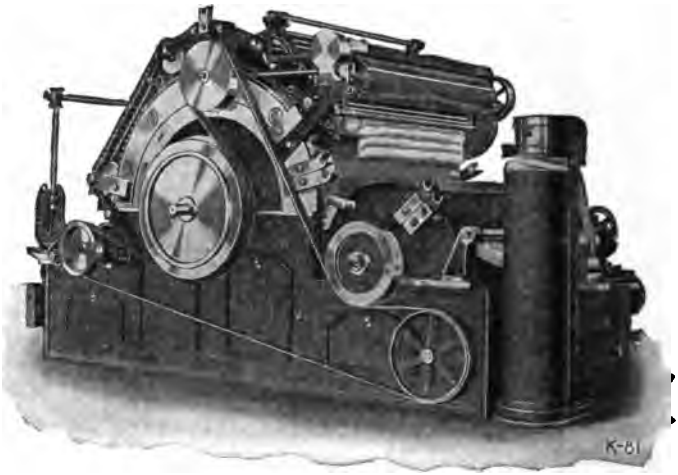

FIG. 4. SEC. 10rr.—Cotton card, equipped with ball bearings, on main cylinder, doffer and locker in.

The arrangement of the "doffer slow motion" of a Whitin Machine Co. machine is shown in Fig. 6, Sec. 10rr. The doffer motion is slow, about 13 to 15 R. P. M. being the average.

COTTON VERTICAL OPENERS.—In vertical openers, trouble is often met with in keeping the thrust bearings in the step of the vertical

FIG. 5. SEC. 10rr.—Doffer comb box, knocked down, showing ball-bearing construction.

spindle in good shape. It is difficult, in the old type of machine, to get at this bearing to lubricate it, and it is often neglected. As a result, it is often heated up and very often water cooling was resorted to. The speed is high and the wear on the bearing is, as a result, excessive.

In the modern types of vertical openers, such as the Saco-Lowell,

ball bearings are used throughout. The lubricant recommended for these bearings is a neutral, No. 0 or No. 1 grease. The cups can be filled about once every three weeks in the usual machine.

Fig. 7, Sec. 10rr, shows a vertical opener, sectional view, showing ball bearings.

For "*card lubrication.*"—On cylinder-shaft bearings, with open lubricating wells, use a No. 3 cup grease. On some types use a semi-fluid lubricant of seven-eighths consistency, or an oil of 275 Vis. (P. B.), or 350 Vis. (A. B.).

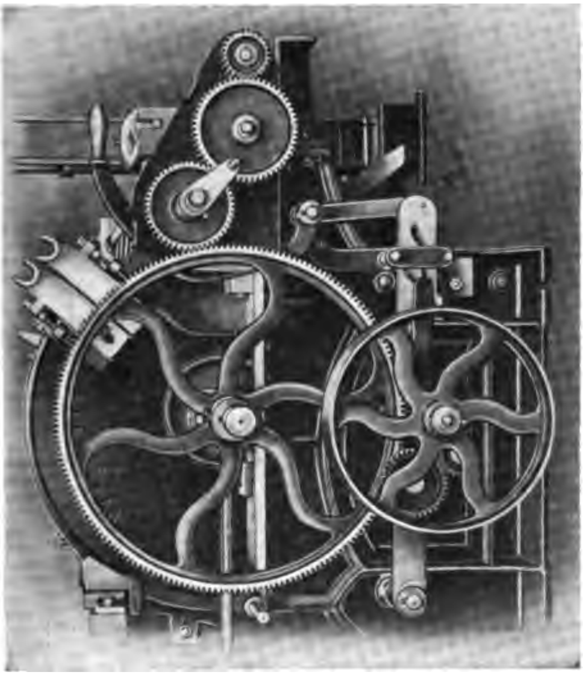

FIG. 6. SEC. 10*rr*.—Doffer slow motion.

For the doffer-comb box use a semi-fluid lubricant of five-eighths consistency. For ball bearings use a No. 1 neutral grease.

For bearings of cylinders, equipped with self-oiling boxes, use a semi-fluid lubricant of five-eighths consistency, or an oil of 275 Vis. (P. B.), or 350 Vis. (A. B.).

For "licker-in bearings" use same as above, also for general lubrication of "feed rolls." For doffer gearing use a No. 3 grease.

COMBING.—"*Tape Condenser*": This machine is used to rub the cotton from the card directly into yarn, ready for spinning. For the lubrication of this machine, a semi-fluid lubricant of one-half consistency, or an oil of 250 Vis. (P. B.), or 300 (A. B.), is recommended.

The "*Sliver-Lap Machine*": This machine is used to form the sliver, as it comes from the card or drawing frame, into a lap for use on the "Ribbon-Lap Machine," or "Comber." The speed of the machine is slow, being about 90 to 100 R. P. M. for the calender roll.

For roll bearings, lifting rolls, calender rolls, drive shafts, etc., use a semi-fluid lubricant of one-half consistency, or an oil of 250 Vis. (P. B.). or 300 Vis. (A. B.).

The "*Ribbon-Lap Machine*": This machine prepares the lap for

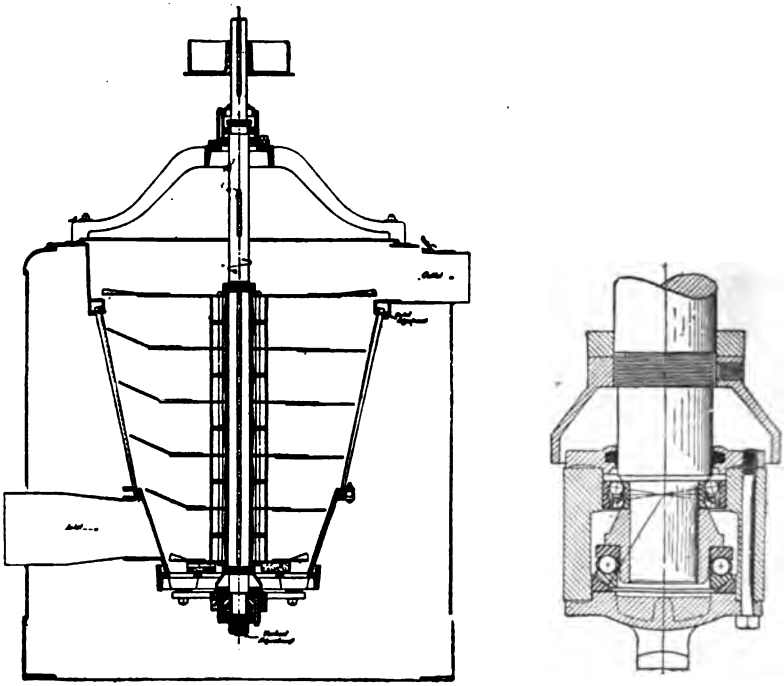

FIG. 7. SEC. 10rr.—Sectional view of vertical opener, showing S. K. F. ball-bearings.

the "comber." For roll journals, pressing-roll necks, drive-shaft bearings, etc., use a semi-fluid lubricant of one-half consistency, or an oil of 250 Vis. (P. B.), or 300 Vis. (A. B.).

The speed of the machine is low, being about 90 to 100 R. P. M.

The "*Combing Machine*": This machine is used to improve the evenness, lustre, and strength of the yarn. The laps are thoroughly straightened and combed by it.

For the gears and cam use a No. 2 cup grease. For other general lubrication use a semi-fluid lubricant of one-half consistency, or an oil of 250 Vis. (P. B.), or 300 Vis. (A. B.).

The speed of this machine is about 120 to 130 "nips" of the comber per minute. The lower number being for long stock and the higher number for short stock.

Fig. 8, Sec. 10rr, shows an improved combing machine, made by the Whitin Machine Works.

The *"Comber Aspirator":* This is an improvement designed to keep half laps clean and to remove noils, fly, and dust from the comber brushes and needles.

It consists essentially of a small fan, which is placed underneath the headstock of the comber. This fan runs at about 1000 R. P. M. and creates a vacuum, which takes the noils off of the brush and carries

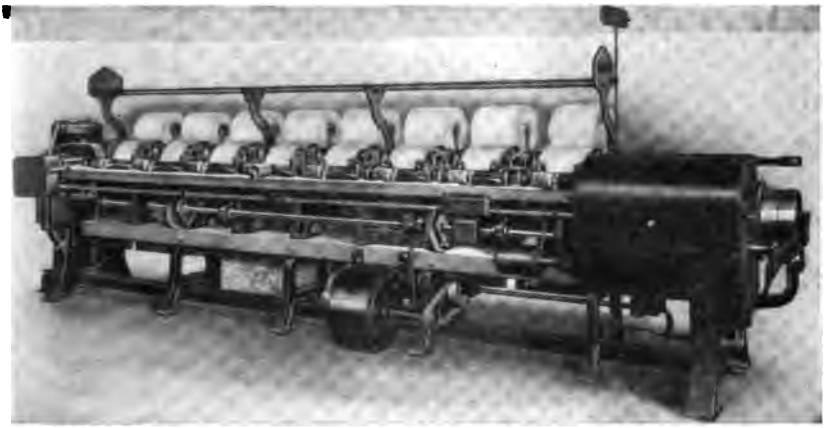

FIG. 8. SEC. 10*rr*.—Improved combing machine, front.

them to perforated drums. The bearings of the fan are usually equipped with ball bearings, and should be lubricated with a No. 1 absolutely neutral grease.

DRAWING.—For the draught gearing, calender rolls, roll bearings, cam tables, etc., of these machines use a semi-fluid lubricant of one-half consistency, or an oil of 250 Vis. (P. B.), or 300 Vis. (A. B.). In some cases a lighter lubricant is desirable on the roll bearings.

The front rolls run at about 250–450 R. P. M.

Some machines are equipped with ball bearings, and for these use a semi-fluid grease of seven-eighths consistency.

For the gears, a No. 3 cup grease can be used with success.

COTTON ROVING.—On "slubbers," "intermediates," and "roving frames" use the following lubricants:

Fig. 9, Sec. 10rr, shows a section of a roving frame, including the flyers and bolster rails for carrying the bobbins.

For "differential motion" (see Fig. 10, Sec. 10rr) use a No. 3 cup grease, or a semi-fluid lubricant of five-eighths consistency, applied with an oil can having its spout enlarged to facilitate feeding.

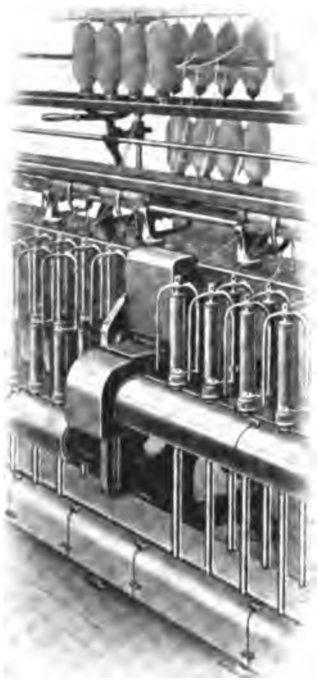

FIG. 9. SEC. 10rr.—Part view of cotton roving frame showing some of the flyers and the bolster rails carrying the bobbins.

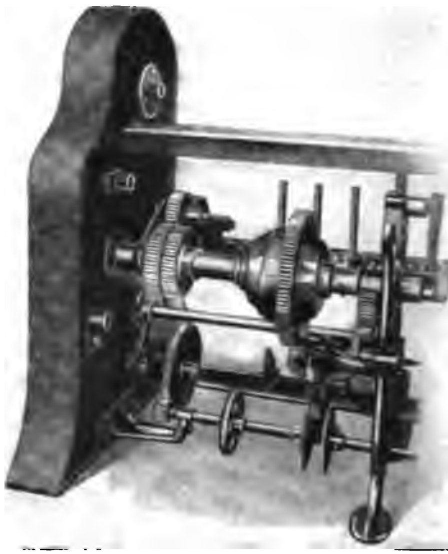

FIG. 10. SEC. 10rr.—Differential motion.

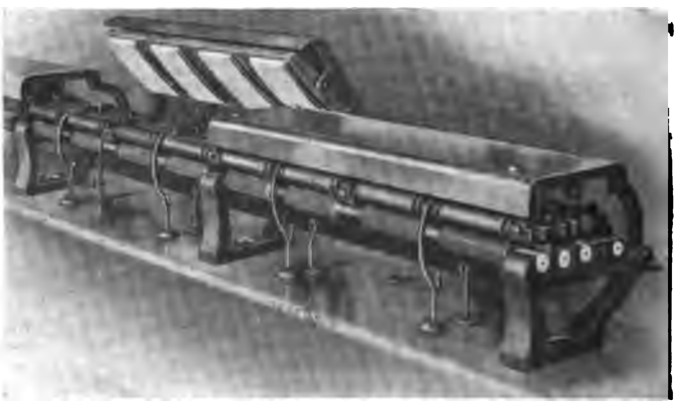

FIG. 11. SEC. 10rr.—Roll and cleaner.

For the cams and draught gears use same recommendations as above.

For "roll necks" use a semi-fluid lubricant of one-half consistency, or an oil of 200 Vis. (P. B.), or 230 Vis. (A. B.).

For spindle steps, provided with reservoirs, use an oil of 175 Vis. (P. B.).

On some machines a grease cup is provided for every four spindles, and for this lubrication use a No. 4 cup grease. For the bobbin gears and compound, use the same recommendations as for roll necks.

Fig. 11, Sec. 10rr, shows some rolls and cleaners.

SPINDLES

The spindle has been developed to a high degree of perfection. A well-known authority states that there are over 500 patents covering improvements on it.

Spindle speeds usually average between 8000 and 12,000 R. P. M. The spindles support bobbins, on which the yarn is wound.

The size, or capacity, of a textile mill is usually given as the number of spindles it has in operation.

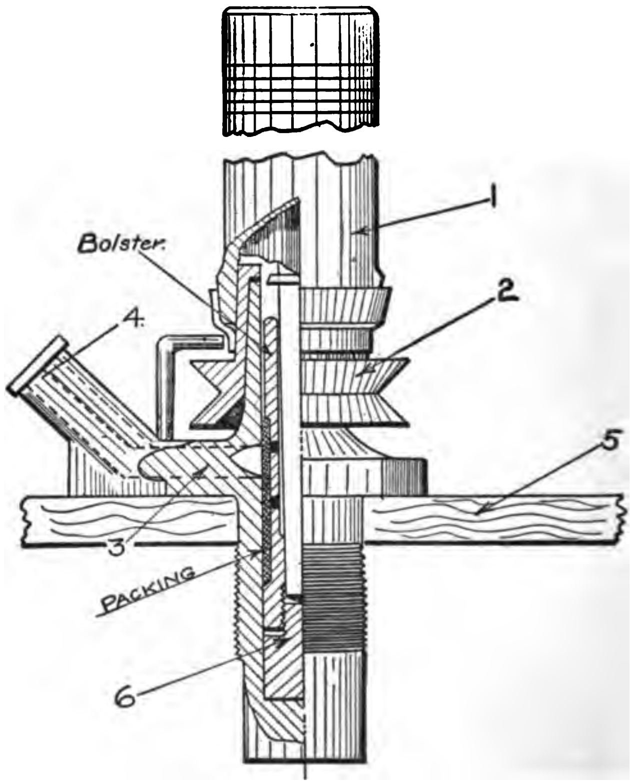

FIG. 12. SEC. 10rr.—Sectional view of a spindle and oil chamber.

Fig. 12, Sec. 10rr, shows an elevation of a well-known type of spindle and a sectional view of the same. Referring to the figure:

1. Spindle blade.
2. Whorl.
3. Oil cup.
4. Oil-filling tube.
5. Spindle rail, on which the cup is mounted.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications. (OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

The end of the spindle is blunt and bears on the plug, or " bolster," 6. (In some types a step bearing is provided.)

It has been stated by several authorities that a spindle under average

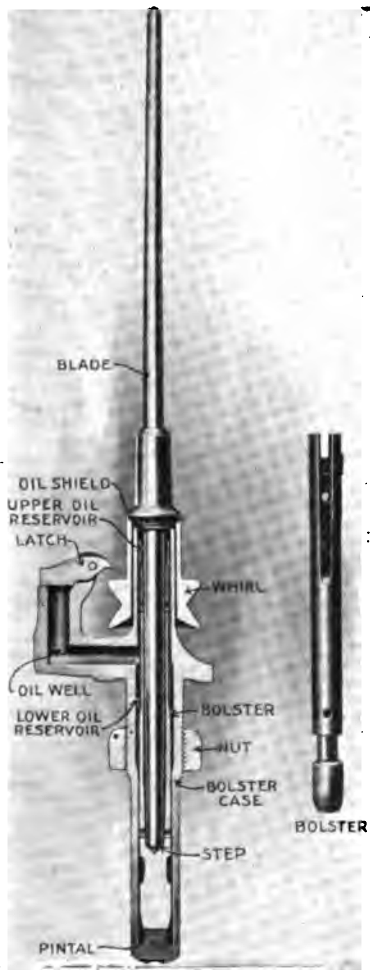

FIG. 13. SEC. 10rr.—Section of improved gravity spindle.

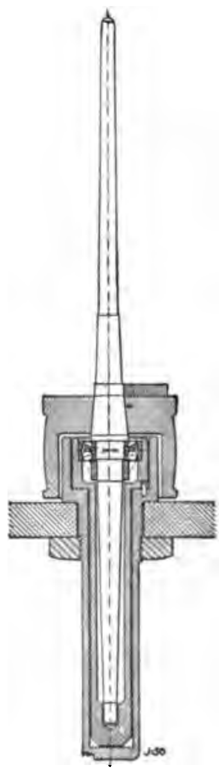

FIG. 14. SEC. 10rr.—Section through twister spindle.

conditions and revolving at 7000 R. P. M. consumes about 0.00750 H. P., and one revolving at 11,000 R. P. M. uses 0.01625 H. P.

Fig. 13, Sec. 10rr, shows an improved gravity spindle, Whitin type.

Fig. 14, Sec. 10rr, shows a sectional view of a ball-bearing, ring-twister spindle.

SPINDLE LUBRICATION.—The effect of spindle speeds upon the horse-power consumed is illustrated by the following table of tests, taken on motor-driven "ring spinning frames":

472 Spindles (2¹/₈-inch Gauge, No. 33s Yarn).

Cylinder Speed	Spindle Speeds R. P. M.	Power Consumed, Plain Cyl. Bearings Horse-power	Ball Bearings Horse-power
790	8,500	4.90	4.38
870	9,300	7.17	6.24
1000	10,800	10.62	9.12

364 Spindles (No. 24s Yarn).

	Cylinder Speed	Spindle Speed	Power Consumed	Number of Spindles per Horse-power
Plain-bearing spindles.....	820	8,220	4,133	88
Ball-bearing spindles.....	840	8,380	3,906	93

Slippage caused by oily "fly" and tight-running cylinder bearings amounts to 10 per cent. to 15 per cent.

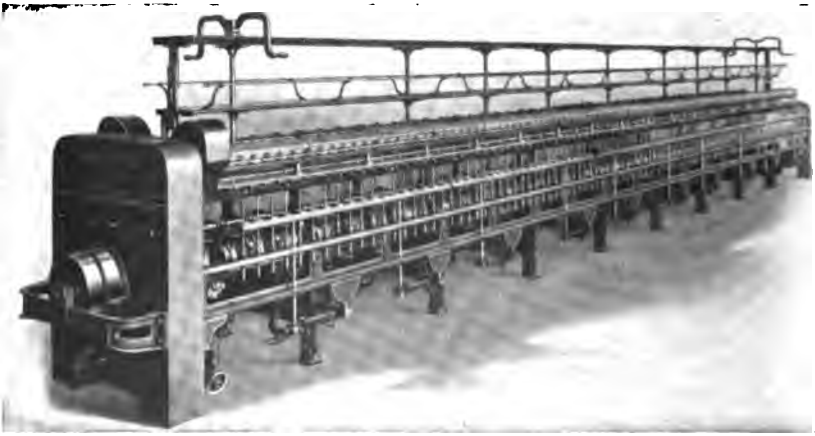

FIG. 15. SEC. 10rr.—Ring spinning frame, with tape-driven spindles.

On tape-driven machines, the cylinder bearings are subjected to a tape pull, all on one side of the bearings, while on band drives this pull is equalized.

Spinning and twisting conditions vary widely, due to the weight of the traveller, top-roll weight, speed, twist, etc.

When the spindles are efficiently lubricated, the easy driving will produce more uniform yarn, full theoretical twist, reduction in belt slippage and bands, and consequently higher spindle speeds, less breakage of yarn and stronger yarn.

FIG. 16. SEC 10rr.—Tape drive.

On band-driven spindles, the variation in humidity, the spindle-bearing temperature, the oil, the condition of the bands, all affect the proper operation of the spindle.

FIG. 17. SEC. 10rr.—Adjustable ring in plate holder.

RING SPINNING.—The power required to drive a "ring-spinning frame" is dependent upon the following factors:

(*a*) Lubrication.
(*b*) Number of the yarn.
(*c*) Speed and weight of the spindles.
(*d*) The length of the traverse.
(*e*) The diameter of the rings.
(*f*) The temperature and humidity of the room.
(*g*) The tension of the bands.

Fig. 15, Sec. 10rr, shows a Whitin ring-spinning frame.

Fig. 16, Sec. 10rr, shows a tape drive. Fig. 17, Sec. 10rr, shows a ring and plate holder. Fig. 18, Sec. 10rr, shows a ring and traveller and a portion of the ring rail.

For the back rolls use a No. 4 white fibre tallow-type cup grease. For the rings use a No. 3 or No. 4 white tallow-type cup grease, applied

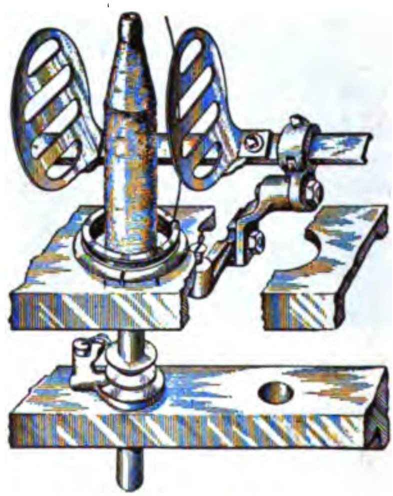

FIG. 18. SEC. 10rr.—View showing ring and traveller and portion of ring rail.

to the rings with the finger, or a heavily compounded oil (lard oil), applied with a brush. Lard oil and home-made tallow mixtures are sometimes used.

"**SPOOLERS.**"—The bolster case of the spindles of spoolers are provided with an oil chamber. The machine averages about 200 spindles per horse-power. Same lubricating conditions as previously described.

SPINDLE LUBRICATION NOTES

It is essential that spindles be lubricated with oils especially prepared for that purpose. These oils must be limpid and free-flowing. They must, however, possess sufficient viscosity to form a protective film of lubricant between the bolster and the spindle.

The oil should have a good evaporative test. When heated for 12 hours at a temperature of 150° Fahr., the oil should not lose more than 4 per cent. (See Oxidization and Spontaneous Combustion, index.)

The flash test of any oil used in the lubrication of a textile mill should never be below 325° Fahr.

Excessive viscosity of spindle oils will tend to greatly increase the friction load of the mill.

The following viscosities are suggested as a guide for the selection of spindle oils for various purposes:

For bath or Rabbeth spindles, doublers, etc., 95 to 100 Vis. at 100° Fahr (P. B.).

For mule spindles, cap spindles, open bolster, sawyer-type spindles, etc., 140 to 150 Vis. at 100° Fahr. (P. B.), 170 to 180 Vis. at 100° Fahr. (A. B.).

For the general lubrication of ring-spinning frames,, cap-spinning frames, etc., 140 to 150 Vis. at 100° Fahr. (P. B.), 170 to 180 Vis. at 100° Fahr. (A. B.). (See previous page for ring lubrication.)

For the lubrication of the front and top rolls of cap-spinning frames and for mule frames, 270 to 280 Vis. at 100° Fahr. (P .B.), 400 to 425 Vis. at 100° Fahr. (A. B.).

A good rule is to oil all spindles on the frames at noon hour. There are several makes of bolsters. The old type required that the spindle be lifted from the bolster and the oil poured into it. When the spindle is replaced in this type, the excess oil is squeezed out and usually drips on the frame and then to the floor. In other makes of bolsters, the oil is poured through a tube into an oil cup, making possible the oiling of a great number of frames per day.

" Rail rods " should be oiled every week, when the rails are washed. Oil on the rail rods lasts a long time, and they require only a small amount.

The other parts should be oiled at least twice a day.

In mills of any size, amazing results will be produced, if a special man, or boy, is detailed to attend to the oiling and wiping of the many bearings, with some degree of regularity. It will pay large returns to any millowner if he will spend some of his time in investigating the lubricating conditions in his mill.

Bands on whorls should have a tension of about 2 pounds. If these bands are too loose, slipping will occur, and if too tight, they will cause a considerable increase in friction. These bands are usually made of twisted "roving," and they are passed around a cylinder, five or six inches in diameter, which runs the length of the frame.

The temperature of the spindle bases will exceed that of the room temperature by about 15° Fahr., normally. A reduction of the temperature of the bases is an indication that the friction of the frame has been reduced.

TWISTING FRAMES.—Fig. 19, Sec. 10rr, shows a twisting frame. For "dry twisting" the bottom rolls are usually made of steel and the top rolls of polished cast iron. For "wet twisting," the bottom rolls are made of brass.

In wet twisting, the yarn is drawn through water, which is contained in a trough, which is located behind the rolls. The troughs are arranged so that they can be connected with the mill water system.

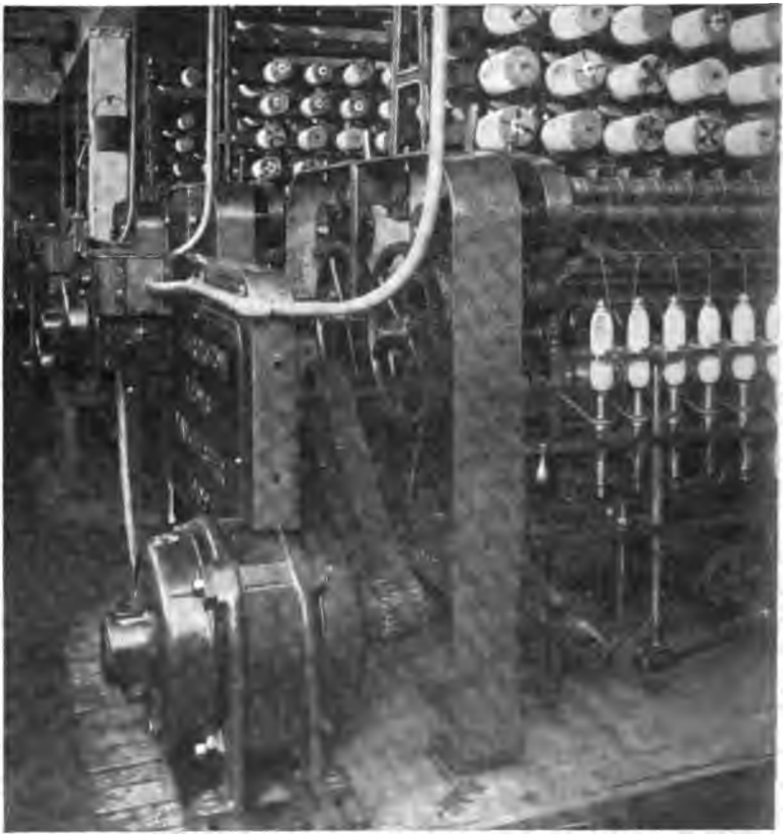

FIG. 19. SEC. 10rr.—180 spindle twister frame driven by electric motor.

The lubricant used on twister rings for traveller lubrication should have no tendency to drip or spatter. When an end breaks down, and the rings are "overoiled," the yarn lashes the lubricant in all directions and staining is increased. The traveller must be lively and offer little resistance, except that due to the air, which condition implies good lubrication. If the traveller drags, there will be broken ends more frequently.

The rings are the life of a twister, and if not in good condition they are practically useless. Usually the cause of trouble with ring twisters is due to excess heat being generated, due to too heavy work and using an oversized traveller, or due to the rings being in bad condition, or, lastly, due to poor lubrication.

Some twister manufacturers supply lubrication for their rings by drilling a hole through the front of the ring and fixing a small grease cup to each ring. For these grease cups use a white tallow-type grease of either No. 4 or 4 1/2 consistency.

For wet twisters, a No. 2 or 2 1/2 white tallow-type grease, applied with the finger, or a lard-compounded mineral oil, filtered type, applied with a brush, is recommended. One objection to tallow for this purpose is the characteristic blackening of the rings which it produces. The lubricant used must not tend to foul the rings and rails.

For the "twist and builder motion," which are usually encased in a box end, use a medium cup grease, or a heavy machine oil. For the spindles see spindle recommendations.

The following information was given the author, by one of the largest manufacturers of twisters in the United States. It is descriptive of recommendations made in the days of fine twisting, before the advent of large sizes, but may prove interesting: "Wet twisters are the most difficult to run and the least understood of any machinery in the mill, owing to the trouble in keeping the rings in proper condition; they being the life of a wet twister, and if not in good condition they are rendered practically useless. The best formula for a lubricant and manner of applying the same to the rings and otherwise caring for them, and one used by the best-informed parties on wet twisters that we know of, is as follows: Take 10 pounds of leaf tallow (be sure it is made from the leaf) and mix with it one quart of lard oil; melt them together and then let the mixture harden. When cool, it should be about the consistency of butter. If not as soft as this, add more oil. Take some of this mixture and rub it on the inside of the ring, using a piece about the size of a small pea for each ring. Do this two or three times a day as found necessary. Besides oiling as above, take lard oil and apply it twice each day with a small brush (one about the size of a common pencil) to the outside of the rings. This will prevent them from gumming, which is caused by the gum in the cotton coming in contact with the water. If you use sperm oil it will gum the rings and spindle oil will stain the yarn. The ring rails should be taken off the twisters every week or two and the rings washed with sal-soda water, using a piece of waste to wash off the grease which has collected. Do not use any alkali, but sal soda, as everything else will rust the rings and make the traveller chatter. Brass plate ring rails should be reversed once every seven or eight weeks."

WINDING MACHINES.—The principal points to be considered in the lubrication of these machines, in the order of their importance, are: The head-end bearings, the roll shaft, the top and bottom jack shafts, the cams, cam shaft and the traverse motion.

A typical machine is put up in five sections, of 20 spindles each, 10 to a side, making a total of 100 spindles per machine. Estimated power per machine is 4 H. P. Power delivered through top jack shaft, to gear, to cam shaft. Cam shaft speed about 350–400 R. P. M.

"Head-end Bearings": There are five boxes on the head end of the frame, with swinging metal covers to keep foreign matter from the bearings, and slotted to hold the lubricant and allow it to pass through the bearing to the shaft. Brass bushings and babbitt-metal bearings. Shaft diameter, 1 1/4 inches. Head-roll speed, 1800-2000 R. P. M. Head cam-shaft speed, 350–400 R. P. M. For the lubrication of these bearings, the best results are obtained by the use of grease. A smooth mixed fibre grease will give the best results.

"Roll-Shaft Bearings": These bearings carry about a 5/8-inch shaft, and are plain brass, open-top bearings. They are 1 inch between rolls, and there are about 51 to a side. The top of the bearing is hinge-covered, to receive and hold the lubricant. The important factor in regard to the lubrication of this bearing is the necessity of using a lubricant which will not thin down and run out of the bearing, and thence run onto the roll, as this roll is in contact with the yarn, which is being wound onto the cones. For the lubrication of this type of bearing, a No. 5 white, firm grease is recommended (tallow type).

"The Cams": The cams are made of cast iron. They are slotted around their entire periphery, to receive the dog, which is designed to actuate the traverse and give it a reciprocal motion. The cam is of special cast iron, while the dog is made of special hardened steel. For the lubrication of this cam a No. 3 grade of graphited grease is recommended. The reason for using this type of grease is to give to the cam a smooth skin, by filling in the pores of the iron, which is softer than the dog, so that the wear on the cam will be reduced to a minimum.

"Top and Bottom Jack Shafts": These bearings are fitted with brass bushings and are designed to be lubricated with a squirt can. Their speed is about 700 R. P. M. A medium consistency, semi-fluid grease, which can be fed from an oil can by cutting the spout of the can off for a short distance, so that the grease will feed, is recommended, or an oil of 275 Vis (P. B.). or 350 Vis. (A. B.), may be used.

"The Traverse Motion": The cone guide is made in two parts, the dog, which slides in the cam, and the body of the guide, which feeds the yarn back and forth along the cone, as it is built or wound. The "arm," or "body," slides on a flat steel plate, and this sliding action is very rapid. It is important that the lubricant used for this lubrication be of such a nature that it will feed evenly and slowly. It must be of the so-called stainless nature. Oil is not suitable, because it will not stay on, and it will drip onto the yarn, while grease would be scraped off.

The most satisfactory lubricant is a semi-fluid white grease of medium consistency; that is, about half-way between a fluid oil and vaseline.

"The Cam Shaft": The bearings are of babbitt metal, and are fed with lubricant through a brass tube leading from the top of the frame.

A semi-fluid grease of medium consistency is recommended, or an oil of 275 Vis. (P. B.), or 350 Vis. (A. B.).

"*The Belt Shipper on the Cone Pulleys*" is driven by a worm gear from the lower jack shaft, and a crank from the gear imparts reciprocal motion to the belt shipper. For the lubrication use No. 3 graphited grease for gear and worm.

In those types of winders ("Universal type") where the operating mechanism is carried in oil reservoirs, to provide automatic lubrication, a light machine oil of 200 Vis. (P. B.), or a semi-fluid lubricant of one-eighth consistency of vaseline is recommended. The gears in the "ganier case" of these machines revolve on a vertical shaft. From the drive

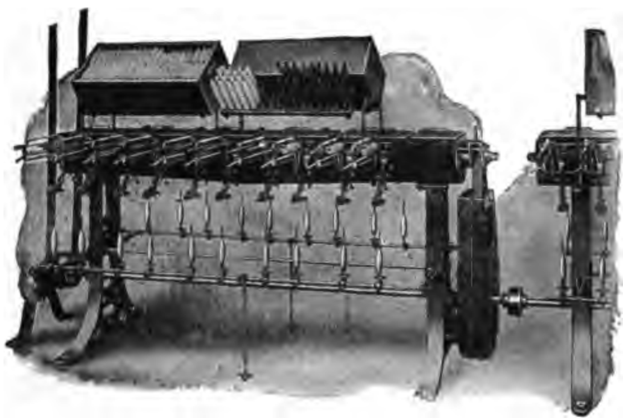

FIG. 20. SEC. 10rr.—Universal No. 90 winder.

shaft the rocker shaft derives its motion through bevelled gears, a pinion, a larger gear, and a pinion and a large gear. The large gear being on the same shaft as the slotted cam, which operates the rocker shaft, through the rocker shaft engaging the cam. Adjoining the ganier case there are several frames, or cases, containing the bobbin-driving mechanisms, two bobbins being driven from each case. Each frame contains two gears, known as "spindle gear right" and "spindle gear left." The frame boxes are connected in a manner that will permit the lubricant level to stand about the same in the different boxes. The frame cases are made deeper on the side on which the gears are and shallower on the other side. The level for lubricant in these cases is indicated by the manufacturer. Fig. 20, Sec. 10rr, shows a winding machine of this type. Some machines making packages with parallel sides are equipped with ball bearings.

PROCESSING WOOL

WOOL.—The fibres of the best wool are made up of a series of elongated cells, that taper toward each end. These cells are covered with the "epidermis," or outer surface, which consists of a series of scales, that range in size from about .0003 to 0.001 of an inch in diameter. These scales overlap, more or less, like the scales of a fish. Fig. 21, Sec. 10rr, shows an enlarged view of a wool fibre.

There is a relation between the wavy, scaly nature of the wool fibres and their felting, or shrinking, characteristics. If two fibres of wool are rubbed together, the scales of the outer surfaces are raised and engage each other, thus interlocking the fibres.

Chemically speaking, wool consists of carbon, nitrogen, hydrogen. sulphur, oxygen, and mineral substances. About 50 per cent. of the fibre is composed of carbon, 3 per cent. of sulphur, 7 per cent. hydrogen, 18 per cent. nitrogen, and 22 per cent. oxygen.

Some authorities have stated, that probably much of the trouble arising when dyeing wool is due to the sulphur content of the wool,

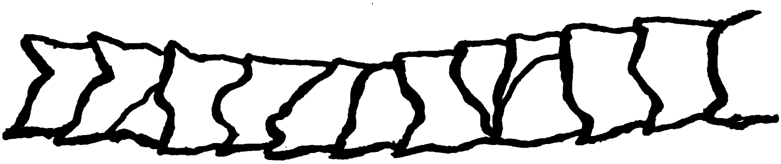

FIG. 21. SEC. 10rr.—Wool fibre.

which may form complex sulphur compounds with the organic dyestuffs. In connection with dyeing, it has been found that wool taken from sheep that have died, and thus containing diseased fibres, does not dye well, because the dye cannot penetrate the outer coating of the fibres. This condition is often unjustly blamed upon the wool oil.

EFFECTS OF ACIDS AND ALKALIES ON WOOL.—Wool is scarcely, or not at all, affected by weak acids, and this characteristic is made use of in the trades in the separation of mixtures of wool and cotton. The mixture of cotton and wool is treated with sulphuric acid (diluted), or aluminum chloride solution, after which the mixture is dried in a temperature of about 230° Fahr., and the cotton is carbonized, and can then be separated as dust from the wool by passing the mixture through a beater.

Caustic alkalies have a destructive effect upon wool fibres, particularly at high temperatures. Textile soaps, which contain an excess of strong alkali, will attack the fibres during the scouring and results in "rotten goods." This trouble is often charged incorrectly to the wool oil.

OTHER WOOL PROPERTIES.—Wool fibre is affected by heat, which causes it to expand, and excessive sweating may cause decomposition.

Wool is a poor conductor of electricity, but is a good generator.

The "suint" which is present in wool is the product of dried up perspiration, and consists of potash salts. It is soluble in water, while the natural grease in the wool, or yolk, as it is called, is not soluble,

MANUFACTURE.—In the manufacture of raw wool into yarn, there are two general processes; namely, the "worsted system" and the "woolen system." In the worsted system, the long staple wool only is worked, while in the woolen system the short staple fibres are also used. In general, it can be said that in the worsted system the fibres of the wool are made to lie parallel to each other, and are made from combed wool, from which the short fibres have been removed, the short fibres being known as "noils" and the long fibres as "tops." In the case of woolen yarns, the fibres lie in all directions, and are matted and intermixed.

WOOL TREATMENT.—The raw wool may be "fleece wool," "pulled wool," or "lambs' wool." Pulled wool is the wool pulled from the pelts of sheep, after they have been lime-treated. This wool is harsh in texture and generally contains some lime, the amount depending upon the care used by the puller. Fleece wool is that wool which is sheared from the sheep and which contains all of the natural ingredients, as later described. Lambs' wool is that wool obtained from the first shearing of the sheep. The wools obtained from different countries and from different breeds of sheep vary, and do not have the same value for manufacturing purposes. The dirt and grease may range as high as 55 per cent. in some of the greasy or pitch wools.

The first step is the sorting of the wool into the different grades and staple. These grades being determined by the uses to which it is intended to put the wool. The wool from the sheep's back contains grease and dirt, and before working it must be removed. This is done by washing the wool in washing liquors, which usually contain soap and soda. The practice of the various wool scourers varies considerably, however, some using only soap, others only alkali, and others both soap and alkali.

The best scouring soap is one that is neutral and free from free caustic alkali or unsaponified fat. It should also be free from resin, mineral oil or other unsaponifiable materials. If the soap contains a great excess of free alkali, it will act injuriously upon the wool and destroy its surface, raising the scales and hurting the lustre. An analysis of raw wool demonstrates that it usually contains some soap. The following analysis is illustrative:

Soap matter	21 per cent.
Water	24 per cent.
Wool fat	10 per cent.
Dirt	3 per cent.
Fibre (wool)	42 per cent.

The soap matter, as indicated, is soluble in water, and is called yolk, or suint. The wool fat is largely capable of mechanically combining with water, forming lanolin. It is used in the manufacture of cold creams for the skin, in ointments, water-proofing, etc.

The washing, or scouring, operation is usually conducted in a washing machine, where the wool, by means of automatic rakes, is passed through the machine. The machine is equipped with three or more bowls, which contain the washing solution. Each bowl is provided with a set of rollers, which are used to squeeze the water and solution from

the wool before it passes to the next bowl. After passing through the last bowl and set of rollers the wool is carried out on an apron or slats to the drying chamber, where, to a large extent, the moisture is evaporated.

The scouring operation requires much care. The stock must be freed from grease, but must not be burnt by too strong a solution or be made harsh. On the other hand, a too weak solution will leave the wool greasy and gummy.

If the wool is made harsh by too hard scouring, it will be found that in the worsted system the fibres become brittle and easily broken and more noil will be produced, while if not scoured enough, so as to be greasy, the stock will roll up on the wire of the cards, and when combed out these "nibs," as they are called, will cause more "noil."

There is another process for removing the grease from the wool, which makes use of naphtha, without the use of soap and water. Some spinners claim that "tops" made from wool that is degreased in this manner are softer in feel and more easily spun than is the case with tops made from the same grade of wool that has been scoured with the other method, using soaps. Lanolin is obtained by this process. Some commercial textile soaps on the market are supposed to contain naphtha in combination with other ingredients.

In the degreasing process which uses petroleum naphtha, as above described, the principle is the so-called solvent method. The valuable grease and potash salts can be recovered, instead of being lost, as in the case of the ordinary scouring method. In this process the wool is submitted to the action of naphtha (petroleum), and this dissolves the wool fat. Next it is subjected to a water bath, where the potash salts and suint are removed, since they are soluble in water. The naphtha is then driven off by volatilization and the wool grease, or "degras," is recovered. (See index for Degras.)

WOOL SUBSTITUTES

SHODDY.—There is also a product known to the trade as shoddy, which may be used in the mix. Shoddy is wool that is reclaimed from soft woolen goods, such as sweaters, stockings, etc. In the process of its manufacture, the rags as received are sorted to give the different grades, and then they are dusted, in a waste duster or willow. This machine consists of a cylinder, which is covered with long spikes and caged in. Underneath is a grating, through which the dust is sucked by a fan. "Seaming" is the next process. The purpose of this operation being to remove the cotton threads from the seams, and also the buttons, hooks and eyes, etc. The rags are then usually dyed, as shoddy that is obtained from rags that have been dyed will give a longer staple and better yarn than shoddy that is obtained from undyed rags and then is dyed after being pickered. The rags are then passed through a grinder, which is also called a "*picker*." This machine firmly holds the rags between a pair of rollers as the rags pass into the machine. In front of these rollers is a revolving cylinder, which is covered with steel teeth, or pins, that unravel the rags into their threads, and also shred the threads into the component fibres. Before passing the rags into the picker they are usually mixed and oiled, for the purpose of softening the rags and helping the fibres to slip easily when pickered. The threads that have not been made into fibre by the picker are "teased out" when the stock is treated in the "garnett machine," or card.

There does not seem to be any distinct division of the shoddies, as in the case of noils and tops, with wools. It is the custom to describe the fibre-reclaimed products, such as shoddy, mungo, etc., according to the rag from which they were obtained, such as tailor clippings, new rags, etc. Mungo is the fibre reclaimed from hard woven and fulled fabrics, the fibre resulting being shorter than shoddy, and may be called a low grade of shoddy.

For pickering woolen rags, saponified wool oil will give the best results. The oil is applied to the rags by spreading out the rags thinly and distributing the oil by means of a sprinkling can. The rags are then left to soak overnight, and longer, if possible, while for very hard worsted stocks 48 hours is required, and even three days. If the time for soaking is not too hurried, the stock will picker easier and card better. It is a good plan to apply the oil boiling hot, either when an emulsion or an oil is used.

For oiling these rags an oil with not less than 10 per cent. of fat is recommended, and the more fat the better for the stock, as better penetration and longer staple will be obtained after the operation. A fair average is about 14 per cent. to 15 per cent. of oil used for woolen rags. In cases where the mill is carding stock that shows signs of trouble in opening the threads, an emulsion is used. Generally about equal amounts of oil and water are used in making the emulsion. The water is heated to the boiling point, and borax, or soda ash, in sufficient quantity is added to the water, after which the oil is added. About one pint of borax, or soda, will handle a barrel of emulsion, and it is important that the water be boiling hot. Do not use too much borax. Generally about twice as much emulsion is used on the stock as would be used if oil was substituted.

In practice, about 100 pounds of rags will give about 75 pounds of shoddy, although, of course, the reclaimed fibre will not have the full working qualities of original wool. In cases where the rags contain a percentage of cotton, as in the case of a wool-and-cotton blend, the rags are passed through the same general processes as described above, except that in order to remove the cotton, the rags are carbonized, in which process they are subjected to a sulphuric acid bath, or to the action of muriatic acid gas, the latter method being on the increase. The cotton is carbonized by these processes, and the carbon can then, after drying, be dusted out, after which the excess acid is neutralized with soda ash.

HAIR FIBRES

HAIR FIBRES AND THEIR CHARACTERISTICS.—There are no epidermal scales on hair fibre as is described in the case of wool fibre, except for the following hair fibres, which have thin, flat scales of large size: Vicuna, mohair, cashmere, and alpaca.

"Mohair" is the hair obtained from Angora goats. It has strength and lustre. Mohair is used in the manufacture of plushes, coat linings, mohair dress goods, railroad plushes for seat coverings, etc.

"Vicuna" is obtained from an animal of that name. It is spun on the woolen system. It is soft and fine, with a shorter staple than alpaca.

"Alpaca" is secured from the alpaca. It resembles the better grades of mohair. It has a length of from 10 to 15 inches.

"Cashmere" is obtained from goats in the Himalayan Mountains. It is soft and silky, and grayish in color. It is usually spun on the woolen system.

"Camel hair," which largely comes from Russia and Asia, is noted for its length and softness. It is worked on both the worsted and woolen systems, but generally on the woolen.

"Horse hair" is gotten from the manes and tails. It is used as a filling with a cotton warp for making haircloth.

"Cattle hair," which is obtained from dead horses and cows, is taken from the hides by pulling. It is blended with low-grade wool wastes and reclaimed wool stock, as it cannot be spun alone. Sometimes it is blended with cotton in coarse yarns, worked on the woolen principle, and intended for cheap rugs, carpets, horse blankets. It is also used blended with cotton and reclaimed wool stock for felts.

MACHINERY

CONE WILLOW, OR DUSTER.—This machine automatically opens, dusts and cleans cotton, shoddy, wool, hair, etc. It is also used to mix and blend two or more grades of stock without rolling or injuring the fibre. The stock is fed onto the feed apron either by hand or by an automatic feeder. The feed apron carries the stock from under the evener rolls to the feed rolls, which, in turn, hold the stock while it is

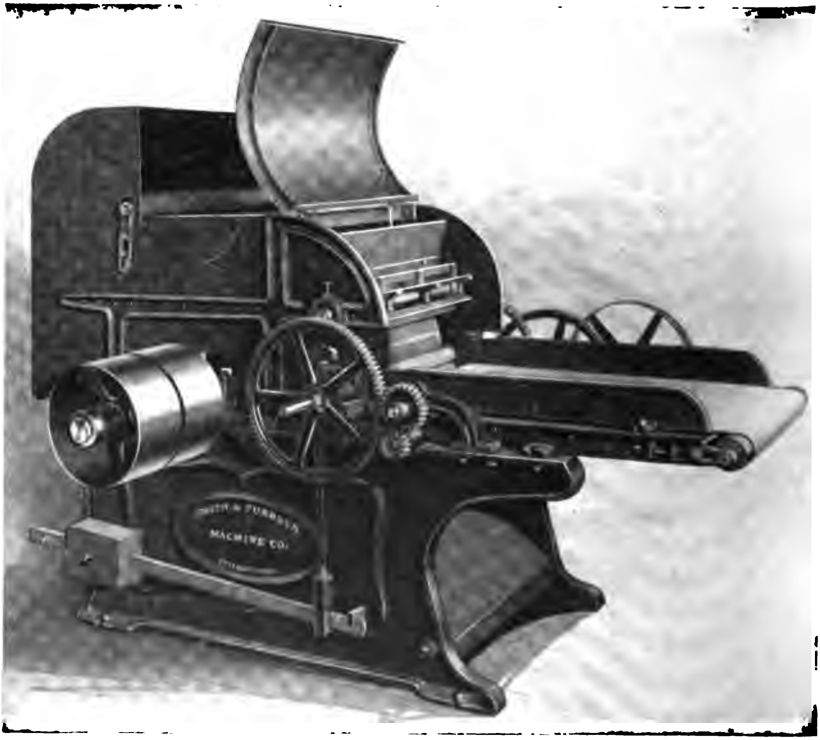

FIG. 22. SEC. 10rr.—Rag picker with gear cover and belt shifter left off.

being taken in by the toothing on the cone cylinder. The stock starts at the small end of the cone cylinder and passes spirally through the machine to the large end of the cone, where the outlet is located. By the action of the teeth in the cone cylinder, which mesh with the teeth in the side rails, the stock is cleaned of dirt and is opened and mixed. The lashing of the stock over the bottom screen and the suction of the dust blower extracts the dust and dirt. The horse-power to drive the machine increases as the length of the cone body. A 6-foot cone machine required

about 6 H. P. to drive. The cone cylinder makes about 400 R. P. M. When the stock is opened and dusted, the clean stock is ejected.

RAG, OR WASTE, PICKERS.—This machine is used to reduce to "pickered stock" all grades of wool, cotton rags, clippings, yarn waste, and jute to such a condition as is required by the waste dealer, or to prepare it for subsequent operations on the garnett machine or card.

In one mill the stock was divided into two parts, one pile containing the raw animal stock, such as cow hair, camel hair, etc. The second pile contained old bagging, carpet, rag stock, etc. The rag stock was treated with "stock oil," by dipping a broom into a bucket of the oil and then spraying the oil onto the stock. This was done to lubricate the mixing while the stock was going through the "rag picker."

The material is placed by hand on the feed apron of the rag picker, and is carried by it to a set of fluted rollers, which hold it firmly while it

FIG. 23. SEC. 10rr.—Three-cylinder garnett machine.

is being delivered to the picking cylinder. This cylinder rapidly revolves, and receives the stock and picks it, discharging it with the aid of centrifugal force, due to the rapid revolutions of the cylinder. There is an arrangement to separate the small bit ends that pass into the cylinder from the nip of the feed rollers from the pickered stock. These small bits are thrown into a box. The pickered stock is delivered at the rear of the machine in the overshot type of picker, or at the front in the undershot type.

The cylinder bearings are usually ball bearings in the modern types. The picker cylinder makes about 800 R. P. M. For a machine with ball bearings, it requires about 6 to 10 H. P. to operate it. The machines without ball bearings are said to require about 25 per cent. more horsepower to drive.

Fig. 22, Sec. 10rr, shows a Smith & Furbush Rag Picker, with the gear cover and belt shifter left off.

As can be seen, there are gears, open bearings, roller bearings, and ball bearings on this machine which require lubrication.

GARNETT MACHINES.—This machine is used to utilize and comb out waste stock when it is either in a tangled or an open condition. The machine cards this waste and restores it to its original fibre, thus saving much material. It is used by manufacturers of woolen or cotton goods. It is adapted to the manufacture of carded batting, felt from cotton linters, waste, fly waste, woolen and worsted thread waste. A large industry has grown up in the United States of buying waste of various kinds and working it up on garnett machines, after which it is disposed of to the trade.

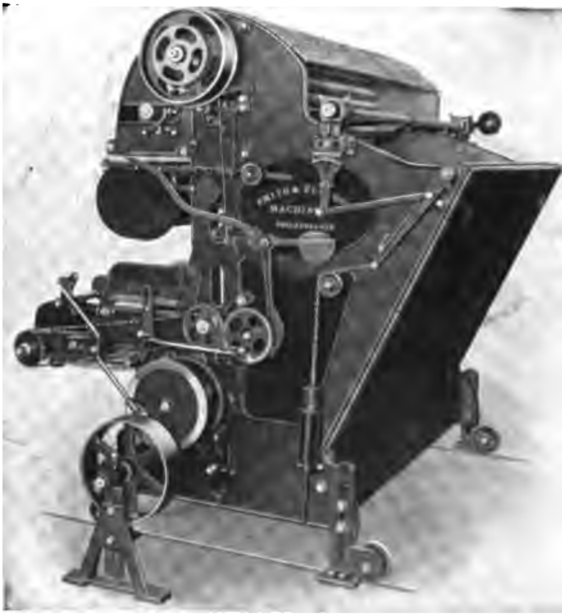

FIG. 24. SEC. 10*rr*.—Automatic self-feeder for cards and garnett.

The garnett machine receives the stock from the "automatic weigher," or after it has been laid by hand upon the "feed apron" of the machine.

The stock is then passed in between a set of metallic feed rolls, from which it is delivered to the "licker in," and thence to the main cylinder of the garnett machine. There is a "lumper roll" in contact with the "licker in" and main cylinder to give a coarse carding contact for smoothing out lumps.

A "breast machine" has a breast cylinder with "workers" that take the place of the "licker in." It acts the same, except that it gives more contacts. The main cylinder carries the stock past a number of workers. These card and smooth out the stock. The stock then passes by a fancy and fancy stripper, which raise the stock from the main cylin-

der, and it is delivered to the "doffer" cylinder. The "doffer cylinder" runs at reduced speed, and the stock is now a uniform, smooth web. It may be delivered to sections of the garnett machine which follow for more carding, after which it is delivered in web form by the "doffer comb."

Fig. 23, Sec. 10rr, shows a three-cylinder garnett machine, as manufactured by the Smith & Furbush Machine Co., of Philadelphia. This machine, as shown, is equipped with a hand-feed apron, retainer roll, 30-inch main cylinders, and 26-inch doffers. The view shows the stock on the feed apron and in the machine.

AUTOMATIC SELF-FEEDERS, FOR CARDS AND GARNETTS.—Fig. 24, Sec. 10rr, shows a view of the automatic self-feeder for cards and garnetts, as manufactured by the Smith & Furbush Machine Co., of Philadelphia. This machine is used for cotton, cotton waste, wool, shoddy, jute, and other fibrous materials, where an evenly distributed feed is required for the machines. This machine is designed to feed the same weight per running yard of stock layer.

FLY-CLEANING MACHINE.—The "fly" is the small particles of yarn that fly off in the carding machine in the carding room. This fly is swept up and put into the "fly-cleaning machine." This consists of a large cylinder, with long steel teeth inserted, and which revolves at a high speed within a casing, that has permanent, or fixed, teeth sticking out at the sides and bottom. These teeth separate the fly from the dirt and grit. The fly is sucked to one side by the air, and the dirt and grit, being heavier, drop into the bottom of the machine. The clean fly can then be put into the willow machine again and made over.

CHART OF WOOLEN AND WORSTED SYSTEMS.—

RAW WOOL	WOOL SUBSTITUTES
Obtained from Australia, United States, South America, South Africa, etc.	Noils Garnetted yarn wastes Shoddy Mungo Extract wool Flocks Soft wastes

WORSTED SYSTEM

(*a*) Sorting
(*b*) Scouring
(*c*) Carding
(*d*) Combing
(*e*) Gilling
(*f*) Drawing
(*g*) Spinning
(*h*) Weaving
(*i*) Dyeing
(*j*) Finishing

WOOLEN SYSTEM

(*a*) Sorting
(*b*) Scouring
(*c*) Carding
(*d*) Spinning
(*e*) Weaving
(*f*) Dyeing
(*g*) Finishing

WORSTED YARN SYSTEM

SCOURING.—The scouring of wools is very important, and many mills that do worsted carding do their own scouring, and deliver the stock to the cards with the proper amount of moisture in the wool.

CARDING.—In the process of carding, the wool is put into the hopper, which is equipped with an automatic feed, which delivers a definite amount, or weight, of wool to the feed apron, which carries it between the cylinders and rollers. Projecting from these cylinders are many small wire ends, called "card clothing." These cylinders revolve in different directions and at various speeds, and they are also of different diameters, so that the results obtained are a straightening out of the fibres and a generally orderly position being given to them. The wool is delivered from the cards in soft strands, by being taken off of the "doffer cylinder" by the "doffer comb," the comb being vibrated by means of a cam and fork at the end of the comb shaft. This cam and fork is contained in a box, called a "comb box," and the lubrication of the comb box is important. It is best secured by means of a medium-flowing grease, of about five-eighths the consistency of vaseline, or a heavy oil, the grease having less tendency to churn. The lubricant must show no tendency to separate and spatter, due to the constant churning given by the swinging fork and cam.

GILLING.—The strand of wool coming from the doffer comb is wound upon a wooden roll, and is known as a "card ball," or "card sliver." The "gilling" operation follows: The sliver from five or six of these card balls is passed through a "gilling machine," which straightens out the fibres. The gilling may be repeated once or twice, according to the character of the stock. On the first of these machines there is a "conditioning pan," generally at the feed end. The amount of conditioning of the stock is determined by the stock, as to whether it is harsh, dry, or has sufficient natural grease to comb properly without conditioning.

Either straight oil, an emulsion of oil and water, or nothing may be added at this point. The wool comes from the gilling machine in soft strands, four of which are then carried to the "balling machine," where they are made into a large ball, and the stock is then ready for combing.

COMBING.—About 18 of these balls are used to make a "set," as it is called for filling the comb.

The comb is used to straighten out the fibres, and the short stock of "nibs" and "noils," as well as foreign matter remaining after carding, is removed, and the sliver comes from the comb with most of the fibres lying parallel.

FINISHER GILL.—From the comb a number of strands are carried to a finisher gill, and is then wound into a large ball, called a "top." The reason for the various gillings has been to secure a stock which has its fibres parallel and a finished top of even and uniform weight.

OILING.—The required percentage of oil is first applied to the top on the first of the gills, at the feed end, after combing from the comb, if the stock is to be "combed in oil." It must also be realized that most of the oil that was added to the card sliver has been combed out of the wool and has gone into the noil.

In regard to the oiling of tops, the fact that they may be stored for several months before spinning into worsted yarn, for the purpose of allowing the fibres to set, is the cause of combing the yarns dry or nearly so, since otherwise the stock may turn rancid. A mineral oil.

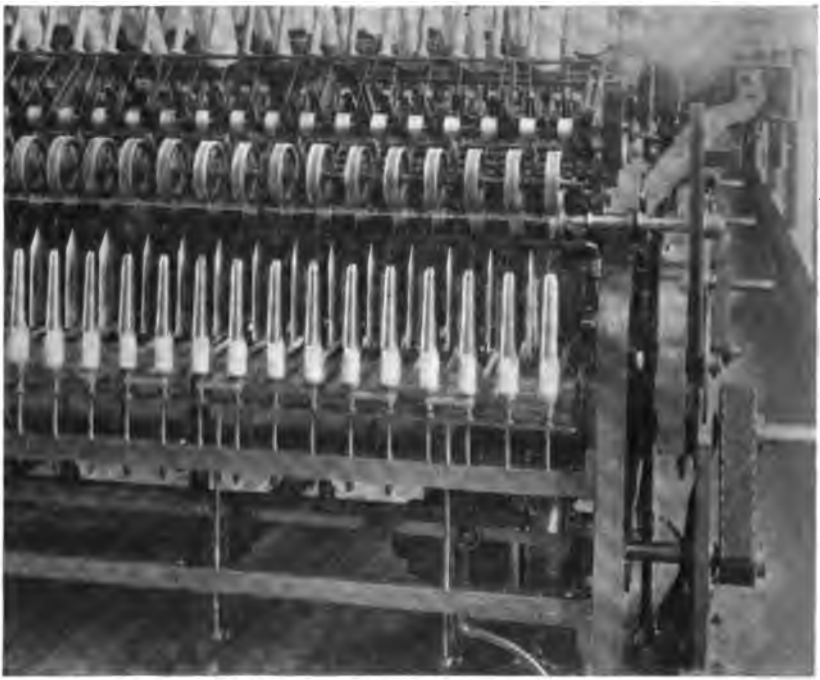

FIG. 25. SEC. 10rr.—Spinning frame.

employed instead of a fatty oil, or heavily compounded oil, is sometimes used to prevent this if the tops are to be stored for a considerable time. The oil must be properly applied, as otherwise the color of the goods will be affected, and if the top is too heavily oiled, or weighted, as it is called, yellow streaks or brown stains will show through and hurt the market value of the stock.

In general, the average mill running on the worsted system, uses only water to condition the stock, because of the necessity for preventing the stock from becoming sticky and gummy, which causes noils and crooked fibres, making it difficult to get good worsted yarn. This last objection is

not so important in the woolen system, since the fibres are in that case matted and crossed.

DRAWING.—Up to this time the wool has received no twist, only a straightening of the fibres, and it has no appearance of a thread. The soft, untwisted end, or top, is next given a draw, by the drawing machines. There are usually about nine distinct operations, during which the stock is drawn and redrawn, until it has been reduced to the size ready for the spinning room, when it is called "roving."

SPINNING.—In the spinning room the stock is drawn and twisted until it is reduced to the size that is required. The threads may be twisted singly, or two threads may be twisted together, and sometimes three or more threads are combined. The yarn is now ready for knitting or weaving.

Fig. 25, Sec. 10rr, shows a spinning frame.

WOOLEN SYSTEM

WOOLEN YARNS.—Most mills running on the woolen system have no scouring machines, and buy their wools scoured. The wool thus bought is expected to be as clean as possible. The cards used in the woolen system are not generally equipped with burr rollers, to throw off the burrs and other vegetable matter which may be contained in the wool. If the wool contains any excess quantity of foreign matter, it is run into a burr picker before carding. In bad cases, the wool is dipped into a bath of chloride of aluminum, or sulphuric acid, and then put through a drier, where the temperature is kept about 212° Fahr. or higher. The heat carbonizes the vegetable matter, but has practically no effect upon the wool fibres.

In the manufacture of woolen yarns, the yarns are spun directly on mules after carding. Thus the fibres have not been paralleled, or equalized, and, therefore, they lie in all directions, as contrasted with the fibres of worsted yarns, which are in orderly arrangement. In the worsted system, the combing operation separates the wool according to its staple length, all fibres under the desired length being removed. The fibres remaining are called "top," and from the top the worsted yarn is made. The short fibres, which are removed are called "noils," and are used by the manufacturer of woolen yarns. Generally noils vary in length from 1/2 inch to about 2 inches, but usually average about 1/2 to 3/4 inch. Previously to the combing, as described in the section on Worsted Yarns, the sliver was treated with an emulsion, and the noil removed from the sliver so treated will contain usually about 3 per cent. of emulsion to the gross weight of the noil.

When the wool is scoured and carbonized the yolk of the wool is removed, together with a large percentage of the natural oil that had been contained in the wool. This natural oil must be substituted by sprinkling the wool with an oil. The best results are obtained if this oil is emulsified with water, as it will permit of a more even distribution of the oil over the fibres, keeping them pliable. Of course, the most important reason for mixing the oil with the wool is to provide a binder for holding the short staple wools together. The oil, therefore, acts as a binder and a lubricant, and it would not be possible to card these wools without its use. Some mills obtain better results by emulsifying the oil with water, to permit of a more even distribution of the oil over the fibres.

The oil mixing is usually accomplished by laying a layer of the wool on the floor and sprinkling it with the oil, or emulsion. Then another layer of wool is placed over the first and sprinkled as described until the desired proportions of wool and oil have been obtained. In order to more thoroughly mix the wool and oil, it is customary to run it through a mixing picker, where it is thoroughly blended and an even degree of oil, or emulsion, is obtained throughout the mix. The importance of obtaining an even mix is illustrated by the fact, that unless this is the case, it will not be possible to obtain an even yarn. The reason for this is that the feeder, which is a part of the first card, weighs off a definite weight of stock at regular intervals. If the mix is too dry, more wool will be taken by the feeder than is necessary to obtain the desired weight yarn, while if the mix is too damp, the increased weight of the oil, or emulsion, will

bring the weight as measured by the feeder up to the fixed amount before the required weight of wool has been secured. This will result in an uneven strand, or roping.

Another point in connection with woolen yarns which differentiates them from worsted yarns is as follows: With the worsted system, the tops are usually stored for a while before spinning, while with the woolen system the yarns are being spun as the "ropings" are taken from the cards. Thus it can be seen that if the roping is uneven, as it comes from the last card, there will be difficulties of many kinds in spinning this roping into yarn. In the case of the worsted system, the "roping," as received from the last card, is given a number of gillings and drawings before spinning, which insures an even and uniform weight yarn.

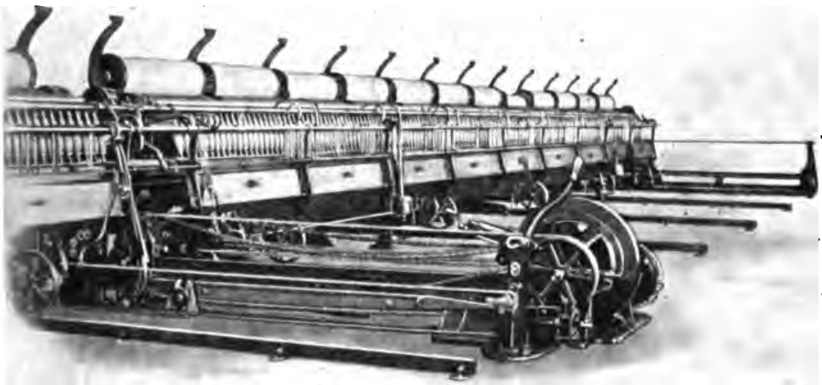

FIG. 26. SEC. 10rr.—Mule spinning frames.

The importance of an even distribution of the oil or emulsion throughout the wool, cannot be overestimated.

MULE SPINNING.—After the yarn comes from the cards and is wound on spools, the spools are placed on a mule and the yarn is wound on the "cops."

The mule on its outward drive draws and twists the yarn, and on its inward drive spins the yarn on the cops. The yarn in this form is ready to be woven into cloth. Fig. 26, Sec. 10rr, shows a mule frame.

REELING MACHINES.—The cops from the mule are then wound on the reeling machine in the form of skein. After the reeling machine is filled with yarn, wound in the form of skeins, the skeins are removed from the frame of the reeler and placed on a scale and made up into bundles of about 50 pounds. If the yarn is kept in the form of a cop, it is ready for use as filling for a loom.

WOOL MACHINERY

PICKER MACHINE.—In this machine, the stock is torn and shredded and sprayed with oil. The oil is pumped onto a cylinder brush, which revolves and throws the spray onto the shredded stock. The surplus oil drains back to the reservoir, where it is strained and pumped back onto the brush in the picker. The cylinder and brushes turn at about 450 to 500 R. P. M. The oiled stock is then sucked up by air pressure to the carding room.

CARDING.—The stock from the picker above described is put into an automatic feed, which weighs the proper amount of stock and feeds it to the "licker-in rolls." The "licker-in rolls" are covered by a card clothing,

FIG. 27. SEC. 10rr.—Woolen cards, electrically driven.

which consists of seven-ply felt cloth, with small steel teeth, running across the surface of the roll. From the "licker-in" the stock goes to a large roll, called the "main cylinder." A doffer removes it from the main cylinder, and from the doffer by a comb. The stock then passes to the travelling apron, which feeds it to what is known as the "camel back."

The camel back is a travelling apron, that carries the stock from the breaker card to the finishing card. The process on the finishing card is about the same as on the breaker card until the stock reaches the doffer rolls. These doffer rolls are cylinders that have rings of card clothing spaced about 1 1/8 inches apart, and run in pairs. The rings on the upper doffer come opposite to a blank space of the lower doffer roll. This is done to give a ribbon effect to the stock, just before it feeds to the "rubbers," or "condensers." The "rubbers" revolve, and at the

same time have a horizontal motion. This horizontal motion gives the stock, now in ribbon form, a rolled-yarn appearance. From this point the yarn is ready to be fed onto spools, ready for the mules. Fig. 27, Sec. 10rr, shows Davis & Furber woolen cards, electrically driven.

Tests have indicated, that with plain bearings, about three to five times as much power is required to start the card as to keep it running. This is largely due to the rubbing action of the plain bearings, and also to the tendency, when the card has been shut down for any length of time, such as overnight or week-ends, the weight of the cylinder forces the oil out from between the shaft and bearing, resulting in a high starting friction.

Many of the new cards are equipped with ball bearings.

One of the factors that must be considered in connection with the lubrication of these machines is the damage to the card clothing that will result if it becomes oil soaked. Card clothing that has not been oil soaked will last much longer. The oil rots the card-clothing backing.

MERINO YARNS; CARDING OF.—This stock is an all-wool stock. When the stock reaches the carding room after passing through the willow and picking machines, it is passed to the breaker card and passes to the camel back, or it may be fed to the "creels." It then goes to a second, or No. 2, breaker card, from which it is fed to No. 3 card by means of an Apperly feed. This feed is an arm, which runs back and forth on a carriage, or guide, and places the stock in layers on a feeding apron of the No. 3 card.

In the manufacture of the finer yarns they always use three or more cards. The process in the carding is the same as described above, as to the operation of the doffer rolls, from which it takes on a ribbon effect, and then goes through the rubber and condenser rolls and is wound onto spools.

SPINNING

WOOL SPINNING.—Bradford, or English, worsted spinning of woolen and cotton mixed stocks must first be very clean. This is accomplished by scouring and washing the wool in alkali waters to remove all sweat, dirt, etc. The first operation is spreading and oiling, which is done by laying the stock about eight inches thick on the floor, and sprinkling the oil on it with a sprinkling can, or by dumping it into a spreading machine, where there is a large hopper, and the stock is then conveyed on an endless belt, which passes it under sprinklers. Up until recent years, the worsted-yarn manufacturers considered that nothing would answer their purpose but olive or lard oils. This was especially true on the finer grades. For sweater or carpet yarns, some manufacturers used a blended oil, taking a 25 or 28 paraffin oil and blending in a certain amount of animal fats, such as degras, the object being to obtain an oil which would readily saponify. This is necessary, so that all oil can be removed from the wool before dyeing the finished yarn.

Later it was found that emulsions could be used to good advantage. In fact, it is now the accepted practice to use emulsions in some of the leading mills.

Of course, there is a slight depreciation in weight in the finished yarns if they are spun with an emulsion, due to the evaporation of the water. This causes some manufacturers to still use oil.

Conditions of machinery, amount of production, and the low cost of emulsions are gradually increasing the amounts of emulsions used.

The main object of oiling is to keep down the fly and to give a more uniform yarn. The French yarns and merinos are spun usually exclusively with emulsions or soap solutions. This is known as the dry process, due to the small amount of oil required to produce the desired results. Some mills use only soapy water.

In all spinning, strong alkalies must be avoided, as they rot the fibre and result in a poor product. Borax, or ammonia, or very weak solutions of potash are the principal alkalies used, and only sufficient to carry in the oil-and-water emulsion.

Sulphonated oils are used in some cases, but they are said to be unsatisfactory, as it is difficult to keep them uniform, and acidified oils have a tendency to darken the fibres; at the same time they are injurious to the aprons, which are made of leather.

WOOL OILS

SPECIFICATIONS FOR WOOL OILS.—The oil used for oiling wool must have the following general specifications:

1. It must be easily washed from the fabric.
2. It must not stain the fabric.
3. It must form an emulsion, which does not create a chemical compound that is dangerous and injurious to the machinery.
4. The viscosity, or body, of the oil must be light enough to secure uniform penetration without oil blotches.
5. The oil must not be so heavy that it will interfere with the rapid-running machinery.
6. It must have the property of keeping the wool in a satisfactory condition.
7. It must have the property of preventing the yarn from becoming sticky and hard after it has been stored for some time.
8. It must be free from drying and semi-drying oils or their fatty acids, and resin oils, since these substances cause stains in the finished cloth, and are difficult to remove in the scouring process. They also become sticky and have an unpleasant odor.

OILING.—The operation of "oiling" is usually performed during the "mixing." The mixing process consists in blending two or more different grades of colors or grades of wool.

The wool is spread out on the floor, and layers of the different grades are sprayed with straight, or emulsified, wool oil from a can, as the mix is made up, each layer of the mix being sprayed with the oil.

In some of the modern plants an oiling machine is attached to the first machine through which the wool goes, and the oil is put on at that point.

There have been many kinds of oil used for the purpose of oiling wool. Olive oil was first used; then rape oil, red oil, or oleic acid, which is a by-product from the manufacture of glycerin, and stearic acid, from tallow.

The development of the reclaiming methods for the soap and wool grease from the waste wool liquor, and the treatment of the recovered grease, or degras, by distillation, brought about the development of so-called wool oils, or oleines, which are oily products of a complex composition.

Under the name of wool oils there are marketed to-day many compounds of mineral oils and fatty oils. Some of the typical compounds used with the mineral-oil base are olive oil, degras, lard oil, oleic acid, tallow oil, peanut oil, etc.

From the standpoint of merely lubricating the wool fibres, almost any oil will do, but there are many other factors entering into the subject, which have very important bearings upon the selection of the best oil for the purpose.

This oil stays in the wool until it has been made into yarn or woven into cloth, when it is scoured out. A satisfactory wool oil will be easily removed from the fabric, and an unsatisfactory oil will be removed with difficulty.

When being carded, the room is always kept at a very warm temperature. The wool oil should never be made into soap, because the water will dry out in the warm carding rooms and a dry soap powder will remain in the wool, which would be objectionable.

The objection of some woolen manufacturers to the use of mineral oils, in their wool oils, is being gradually overcome.

Poorly compounded oils result in the scouring operation carrying away the fatty oil and allowing the mineral oil to remain in the goods, which causes trouble. There are, however, some advantages in a high-grade mineral wool stock. It is free from gum and free acid, preserves the card clothing, and it will cut the gum and natural-wool grease, which may be brought onto the card clothing with the animal and vegetable oils. In the type of wool oil made by compounding a mineral wool stock with animal oils and fats, such as red oil, lard oil, and degras, the alkali in the scouring soap is depended upon to saponify the animal oil and to bring away the mineral oil in solution.

Some wool oils are made similarly to a semi-boiled grease, containing an excess of fat. It is necessary for this purpose to have a good lubricating fat, and, as a rule, these oils are made from a high-grade fat and either soda or ammonia soap, dissolved. For the oil component of these oils, a sun-bleached neutral is used. It has been found, that when

neutral oil is bleached, a slight sterification occurs, which aids the emulsion, giving much better results with the oil than were possible before it was sunned. One of the points that must be watched is the cooking of the oil, for if the oil is cooked too much, so that the water is entirely cooked out, the oil will not emulsify as well as though some water were left in the oil. The soap must not be dehydrated. Better emulsions will be obtained if some ammonia is added when making up an emulsion with water.

A prepared water, containing a very weak solution of a good soap, will hold the emulsion much better than water prepared with sal soda, soda ash, or other alkalies, and a weak solution of soap and water will not dry out as quickly as an alkaline solution. The prepared water and the wool oil are mixed in varying quantities to form an emulsion.

DANGEROUS WOOL OILS.—Another important requirement of wool oils is that they must develop as little heat as possible, when stored in the material and during manufacture.

Various authorities have stated that drying, and sometimes semi-drying, oils may develop spontaneous combustion.

Another feature that must be considered is the speed in which the oil would aid in the spread of a fire. The fire insurance companies in some countries have certain insurance charges, based upon the kind of oils used. In one instance, the terms stated that there was no extra charge for olive and lard oils, with not more than 10 per cent. unsaponifiable matter, or for fish oil containing not more than 30 per cent. unsaponifiable matter. (See index for Mackay Oil Tester.)

Messrs. T. Fairly and B. A. Burrell presented the following facts before the Yorkshire Section of the Chemical Industry at Leeds: White wool, oiled in the usual manner, began to heat; the fact was noticed before the wool actually fired. On analysis the oil proved to consist of about 88 per cent. of fatty acids and 12 per cent. of neutral oil; there was a decidedly fishy smell, and the presence of insoluble bromides indicated a fish origin. The oil lost 66 per cent. on heating to 340° Fahr., which is quite an unusual volatility, and had a flash-point 368° F., open cup. Glycerin being wanted for other purposes, fish oils (largely fatty acids) find various application, but their uses as wool oils seems to be decidedly dangerous. (See index for Drying and Semi-drying Oils.)

The statements of several authorities regarding the spontaneous combustion of oils and oily waste may be summarized as follows:

The fire risk from the spontaneous ignition of oily material is increased the more readily oxidizable the oil is.

Mineral oils, which do not oxidize, do not heat, and are not as subject to spontaneous combustion as those oils which are readily oxidizable. It is generally stated that when a mineral oil is compounded with a sufficient quantity of fatty oil, it will prevent the possibility of spontaneous combustion arising from the mixture. Usually the more mineral oil of 350° Fahr., or more flash, that is in a compounded lubricant, the safer the oil is, as regards fire risk.

Insurance companies, however, consider that the fire risk in the textile mills is increased, when the compounded lubricating oil used contains a large percentage of petroleum oil and a small percentage of compound. This is due to the fact that when a fire is started, the lower flash test mineral oils assist the spread of the fire more readily than the higher flash compound oils.

COTTONSEED OIL AND WOOL FIBRES.—This oil should not be used in wool oils, because it is classed as a drying oil. An emulsion made with cottonseed oil for the oiling of wool before carding would cause the drying effect of this oil to become objectionable on the cards, due to gumming. The proposition has been advanced to use a small quantity—about 5 per cent.—to get an emulsion, but no reports as to results have been received.

WOOL EMULSION PASTE.—A paste for making wool emulsions may be made as follows:

Make a mixture of one-half No. 2 lard oil and one-half red oil. Make a caustic-soda solution of one-half pound of caustic soda, 76°, to one

gallon of water. Have oils at 110° Fahr to 120° Fahr., and add caustic-soda solution at 90° to 100° Fahr.

Beat in a portion at a time, and allow it to mix thoroughly. After solution is in a stiff paste it will take up 1 1/4 of the whole weight with water. Result, a stiff white paste, soluble in water.

Degras is sometimes also worked into the formula, instead of the lard oil.

OILING APPARATUS

TURBO SPRAYER FOR CONTINUOUS OILING OF WOOL.—Fig. 28, Sec. 10rr, shows a part sectional view of the turbo sprayer, and Fig. 29, Sec. 10rr, shows a turbo sprayer used on the apron of a mixing picker with an automatic feeder. The turbo sprayer is manufactured by the G. M. Parks Co., Fitchburg, Mass. The purpose of this sprayer is to improve the conditioning of stock. Instead of adding oil, emulsion, or moisture at one or two machines, it can be added in the right proportion at every machine. In order to obtain the best results, the oil, or emulsion, should be finely divided, evenly applied, and properly measured. In operation, the oil, or emulsion, is supplied by gravity, or by pressure. The rate of flow is controlled by a needle valve, its position being determined by the movement of a pointer over a graduated scale. A pressure blower supplies the air, which passes through the main chamber,

FIG. 28. SEC. 10*rr*.—Sectional view of Turbo sprayer.

through tangential ports to central tip, where the fluid jet is broken up and the spray produced is caught up and distributed by the balance of the air.

AUTOMATIC WOOL OILER.—The Spencer automatic stock-oiling machine is designed to be bolted to the sides of the picker-feed apron. It consists principally of a revolving brush, on which the oil, or the emulsion, is dropped by a vibrating pipe. This pipe leads from a small tank, at the top of the machine.

As the brush revolves, it strikes against a metal blade, and thus makes the oil, or emulsion, go into a spray. This spray is thrown evenly on the wool, as it passes over the picker-feed apron from the feeder to the picker. The oil is thus enabled to penetrate the stock thoroughly. The forward motion of the material and the quantity of oil sprayed by the brush can be regulated by the operator. The Spencer oiler and Bramwell picker-feed, when used together, do away with old-fashioned method of oiling by hand.

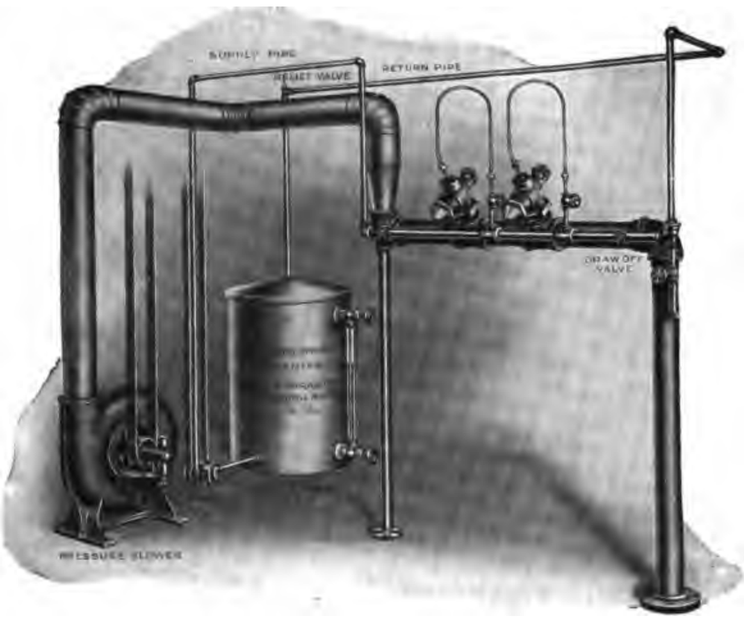

Fig. 29. Sec. 10*rr*.—Turbo sprayer installed.

SCOURING AND OTHER OPERATIONS

TEXTILE SOAPS AND OPERATIONS.—Soaps are used in connection with wool operations in scouring the raw wool, the wool yarns and fabrics, and for milling, or fulling, woolen fabrics.

The wool obtained from the sheep's back contains grease and dirt, which must be removed. This is accomplished by means of washing liquors, that contain soap and alkalies.

The soaps have the property of penetrating the wool fibres and removing the fat, or grease, by emulsifying it, and thus aiding the water to remove it. The most satisfactory soap is one that is neutral and does not contain any free alkali, resin, unsaponified fat, or filling. If the soap contains an excess of free alkali it will injure the wool and impair its lustre. Soaps used for the purpose may be cottonseed oil soaps, olive oil soaps, etc.

Soaps made with potash are softer than soaps made with other alkalies. They leave a softer feel and better lustre than hard soaps.

Wool in the raw state contains some soap matter, as is shown by the following analysis:

Dirt	3.00 per cent.
Soap matter	21.40 per cent.
(Wool sweat, or suint, or yolk)	
Wool fat	9.25 per cent.
(Cholesterol and saponifiable fats)	
Wool fibre	44.00 per cent.
Water	22.35 per cent.

The cholestrol is neutral and unsaponifiable, but will mechanically combine with water to form what is known as lanolin.

For the removal of the oil after spinning (see Wool Oil in index), the wool is generally boiled with an alkali, or soap, depending largely upon the oil used. For instance, an oil containing a large percentage of oleic acid would need a soap containing a good percentage of free alkali to neutralize the acid. If the oil is largely composed of a fatty oil, a neutral, free from alkali soap, is best.

After dyeing woolen cloth, soap is used for "fulling" the cloth. Soft soap, such as those made from olive or cottonseed oils, and in some cases hard soaps, are used. The soap used for this purpose should be easily soluble in water and free from alkali. Sometimes a preparation made from commercial oleic acid (oleine), to which sulphuric acid has been added, and other chemicals, giving a sulphated oleine, is used.

One feature that must be taken into consideration in connection with the scouring of fabrics is the character of the water used. Due to the great solvent powers of water, it will dissolve and carry various substances met with as it flows through the ground. (See Soluble Oils and Water in index.) Calcium and magnesia, if present in the water, tend to form insoluble magnesium, or lime soaps, which appear as curdled masses in the water. These curdy masses, when met with in the wool-scouring operation remain to some extent in the fabric, and dyeing cannot be as well done as a result. Stains are likely to occur.

When washing the cloth where hard water is used, rinse water should be let in to carry the soap off gradually. If the soap is drawn off too quickly, the scum in the lime substance may drop down onto the cloth, and this scum is very hard to remove with clear water.

The alkali in the soap must be in sufficient quantities to entirely saponify the oil, in order that it will wash out easily.

It generally does not require as much soap to remove the oil, if one soaping instead of two soapings, with an intervening rinsing, are used. This is due to the fact that the reduced amount of oil in the cloth allows the fabric to be filled with water, which consequently greatly reduces the strength of the soap solution.

EMULSIFICATION.—Generally speaking, a dirty object consists of a solid, whose surface is covered with a thin layer of greasy matter, in which are imbedded small particles of dirt. This greasy matter is insoluble in water, and its removal is effected by emulsification, which means that some substance is added to the water which causes the grease to be split up into very small drops. This principle enters into the process of scouring.

When olive oil is taken up with water, the oil is split into drops, which are distributed through the water, and after standing these oil drops rise to the surface and form a continuous layer of the oil. If a small amount of alkali is added to the water to obtain a dilute solution of alkali, it will be found that the slightest agitation will cause the oil to be split up into such fine drops that the mixture of oil and water will take on a milky appearance and the solution will hold for some time without the oil separating out. On the other hand, if a little benzine had been used in place of the olive oil, or another mineral-oil product, it will be found that on shaking with the dilute alkali solution, no emulsification will be produced, but if a little oleic acid, or red oil, is added to the benzine, it will be found to emulsify readily in the dilute alkali solution. These actions demonstrate, that the alkali is not the direct cause of the emulsification, but that the effect is due to the soap formed by the interaction of the alkali and the fatty acid. (See index for further data on Fatty Acid and Fatty Oils.) This fatty acid is a component part of the fatty oil, but must be added to the mineral oil, as described in the form of oleic acid. It has been found, furthermore, that fatty oils that have been freed from free fatty acid, cannot be emulsified with alkali, though they contain saponifiable glycerides of fatty acids. (See index for Saponification.)

The explanation of emulsification is interesting. When the oil is split into the small drops, the area of the surface of the oil is greatly increased, and hence the area of the separating surfaces between the oil and the water is increased. This increase in surface is resisted by surface tension. (See index for Surface Tension.) All surfaces that separate two fluids act as though they were coated with an elastic membrane, or are stretched tight, as the head of a drum, which elastic surface resists extension.

If a glass container is partly filled with water and a layer of a fatty oil, such as olive oil, is poured on top of the water surface, and an attempt be then made to push some of the oil into the water, by means of a glass rod, it will be found that resulting action of the surface separating

the oil and water tends to cause the oil to return to its undisturbed form in the main body of oil. If, however, a little alkali is added to the water, and the separating surface is again disturbed with a rod, it will be found that it is easy to project the oil into the water, and the oil thus pushed into the water will be broken into fine drops in the water. Thus the effect of the soap formed by the alkali and fatty acid is to reduce the surface tension.

In the case of scouring, it is important that when the grease and dirt are removed, they must not be redeposited on the product scoured. It must be appreciated that the small particles of dirt and grease are probably removed from small crevices, which afford good places for redepositing.

It has been found by investigators, that under the microscope, the fine particles of a fine emulsion are seen to be in constant motion. This movement is called the "Brownian motion," after its discoverer. It is due to the impacts of the molecules of the liquid, which, owing to the smallness of the particle, do not exactly balance. Thus the particle is driven first in one direction and then in another. And it should be evident that the smaller the particle, the more violent this Brownian motion will be, and the more violent the motion is, the better opportunity the dirt particle will have of getting free from the surface being scoured. It is thus necessary that coagulation of the dirt particles and of the oil droplets must be prevented.

Those who have studied the subject have found that the small particles in water possess a negative charge, while the surrounding fluid portions are positively charged. This electric charge will prevent a coagulation, since "like electrical charges" repel each other, and thus the two particles in their movements repel each other when they approach. It has been further found that when alkali is dissolved in small amounts in the water, the negative charge will be increased; thus the alkali in the detergent solution will tend to prevent coagulation and will also increase the negative charge on the surface of the object, and thus tend to prevent redepositing of the dirt. There is another factor that prevents the coagulation of the oil droplets, which is due to the effect on the surface tension by the soap, which tends to accumulate on the surface in layers and form a semi-solid pellicle, which tends to prevent the union of the oil particles.

One of the most important factors to be considered in connection with wool oil is the removal of the oil. The yarns, or cloth, must be dyed, and in order to do this the oil must be removed from the wool. The usual method for accomplishing this is by scouring with soap, with or without soda or potash. The important property included in this operation is the emulsifying and saponifying action, the soap furnishing the emulsifying effect upon the oil and the soda giving the saponifying effect. If the oil is not entirely removed from the wool, the dyeing will show streaks and spots. While petroleum oils are not saponifiable, they can be combined with fatty oils, oleines, etc, and suitable oils obtained. thus reducing the cost.

FINISHING

FINISHING WOOL GOODS.—Roughly, the amount of dirt contained in a fabric will vary considerably. In woolen goods, which are made from all wool, the amount may be about 15 per cent., while in woolen goods that are made from shoddy, the loss is usually much greater. For worsteds the percentage will be smaller, usually running from 3 per cent. or 4 per cent. to about 8 per cent. or 10 per cent., depending upon the methods of yarn manufacture.

The scouring process and methods vary greatly, according to the character of the cloth and the custom of the mill. However, the following description is typical: The strength of the soap used, the amount of it employed, and the length of time the goods are kept in the soap depends upon the amount of dirt to be removed. The cleaner the cloth, the lower the above amounts.

The goods are put directly into the washer, and kept there for about 20 to 50 minutes. If the goods are hard and firm in construction, it is good practice to run them into warm water, so as to soften them, and thus prevent the formation of "washer wrinkles."

In the washer, the dirt and foreign matter is acted upon by the soap, and in addition by the pressure applied at the nip of the rolls.

The soap should have a creamy lather, after about 25 minutes' use, and this is evidence of a properly working soap. If the soap gets too thick, or a pasty condition develops, it will cause washer wrinkles and streaks in the goods. The soap should never present a thin, watery appearance.

After the action required of the soap has been completed, the soap is rinsed off with aid of warm (110 F.) water, the operation of rinsing requiring about 20 minutes or a half hour. Generally the goods are again put into a soap bath of weaker strength, and are then again rinsed in warm water. It is very necessary in this final rinsing to use extreme care, as it is one of the most important points. The best results are obtained by using plenty of water and not hurrying the operation. All traces of the soap must be removed from the goods. Carelessness in this final rinsing will result in soap streaks, or clouds, which may appear after dyeing. In the case of wool dyes, dull colors will be evident, and a rancid odor and poor-handling goods are the result. The final warm-water rinse may require two hours, and then the temperature is allowed to fall until the water becomes cold, when the goods are removed. This is also an important feature, because the water in the bath must not be allowed to suddenly turn cold, but a gradual change must be brought about, or a harsh feel will be given to the goods.

Washer wrinkles are due to the fabric running too long in the same folds. They are breaks in the cloth, and usually run diagonally. Goods that have been fulled a long time, especially with a tallow soap, should be thoroughly rinsed, or otherwise clouds will result.

Tightly woven worsteds are more likely to take washer wrinkles than other goods, because they do not yield easily to the nip pressure, and there is, as a result, a crack. The roll pressure for this class of goods is reduced to a minimum, but there is sufficient pressure to prevent the goods from slipping, otherwise chaffing will occur. If the scour-

ing soap becomes too pasty, wrinkles are liable to occur, as the folds do not change as often as they should, due to their sticking. It is important that the washer is not overcrowded, as in that case the folds of cloth that are at the bottom of the washer will not change as often as necessary, and wrinkles will form. In order to prevent as much as possible the formation of wrinkles in goods that are particularly susceptible to washer wrinkles, these goods are tacked; that is, they are doubled lengthwise and sewed on the selvages, with a long, loose stitch. This has the effect of making the cloth take on a long and continuous tube effect, and ballooning, which causes the folds of the cloth to change continuously.

Hard and heavy goods that are likely to wrinkle should be washed in an open- or full-width washer, as in this case the cloth being scoured in the full width will not wrinkle and give a firm, compact face. Washer wrinkles should not be confused with creases, as the latter are merely folds in the cloth, that can be easily removed, as they are not breaks in the cloth, as are the washer wrinkles. Creases are generally caused by allowing the goods to run through in rope form, or by letting the goods stay in a wet pile too long.

WEAVING

The weaving operation is described briefly as follows:

The yarn is placed on a spool, by means of a "spooler." This is called "warp yarn."

A "warp" is made by combining a number of threads, or "ends," as they are called, in a carefully planned order of definite lengths, and winding these ends onto a cylinder, which is called a "warp beam."

The spools are placed in definite positions on a frame, called a "creel."

The warp is usually "sized" by passing it through a starch mixture.

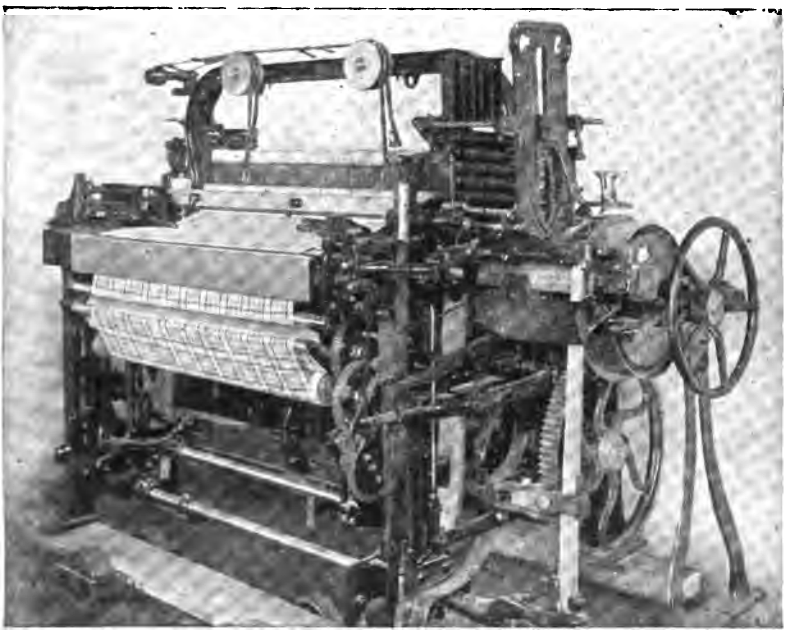

FIG. 30. SEC. 10rr.—Front view of automatic gingham loom.

POWER LOOMS.—The principal parts of power looms are as follows: 1. Frame. 2. Warp beam. 3. Cloth roll. 4. Heddles and their mountings. 5. The reed.

Fig. 30, Sec. 10rr, and Fig 31, Sec. 10rr, show front and back views of an automatic gingham loom, shown through the courtesy of the Crompton-Knowles Loom Works. Fig. 32, Sec. 10rr, and Fig. 33, Sec. 10rr, shows front and back views of a special light duck loom. This loom is also shown through the courtesy of the Crompton-Knowles Company.

The same oils and greases are recommended for use on these machines as are suggested for the worsted looms, etc., above.

WARP BEAM.—The warp beam is usually a wooden cylinder,

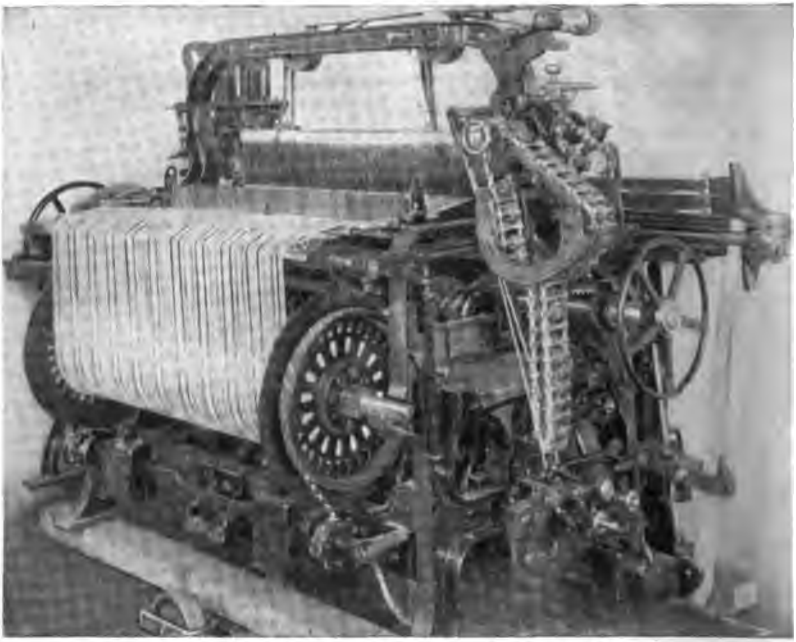

FIG. 31. SEC. 10rr.—Back view of automatic gingham loom.

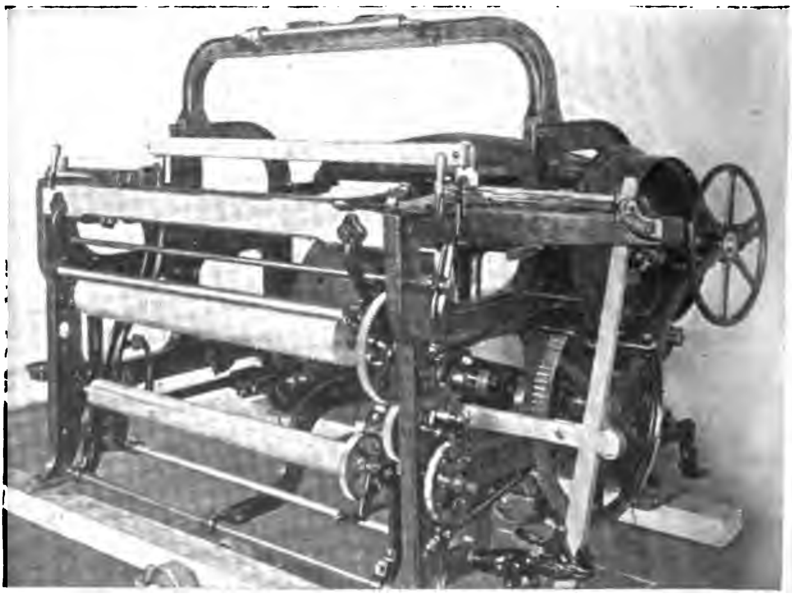

FIG. 32. SEC. 10rr.—Front view of a light duck loom.

which is mounted at the back of the loom, and on this the warp has been wound, as stated above.

The "warp threads" are extended in parallel order to the "cloth roll," which is mounted at the front of the loom. Each thread, or group of threads, is passed through an opening, or "eye," of the "heddle."

The threads are divided by the heddles, and each division is raised or lowered by the movement of the heddles. Each time the "harness" is

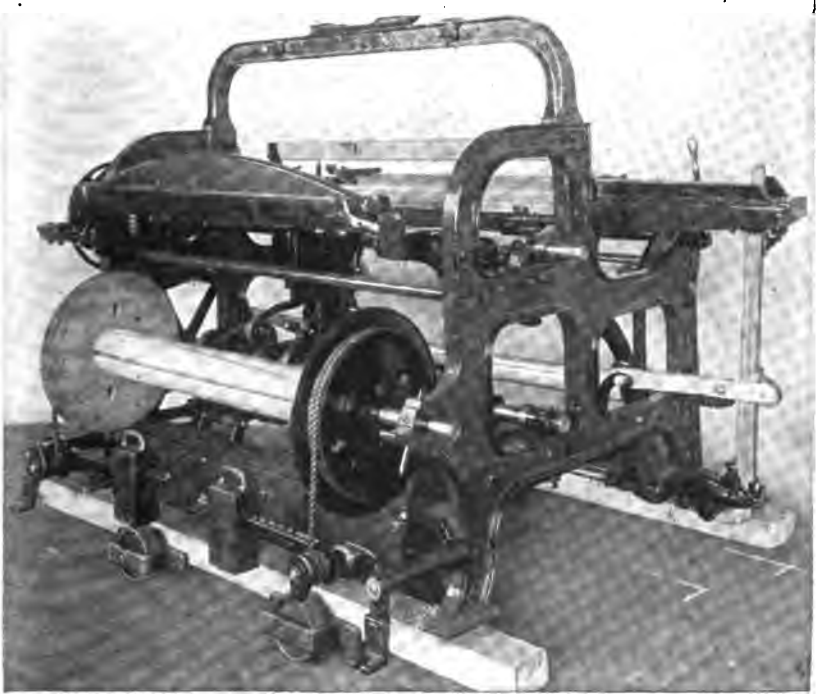

FIG. 33. SEC. 10rr.—Back view of a light duck loom.

pulled up or down, the two or more divisions of the warp threads are separated, so that an opening, called the "shed," is made between the upper and lower warp threads. Through this "shed" the "shuttle" is thrown, and the "filling thread," which is wound on a "bobbin," is carried through with it.

As soon as the filling thread is interlocked with the warp threads, it is pressed close by the "reed," to make the cloth firm and tight.

WEAVES.—(a) Homespun, or plain, weaving has a warp and filling thread running at right angles to each other.

(*b*) Twill has the filling pieces under different warps, and is obtained by moving the warp to the right or the left.

Fig. 34, Sec. 10rr; Fig. 35, Sec. 10rr, and Fig. 36, Sec. 10rr, show two back views, taken from opposite ends, and one front view, of the well-known automatic heavy worsted loom made by the Crompton-Knowles Loom Works, Worcester, Mass., and is shown through the courtesy of that firm.

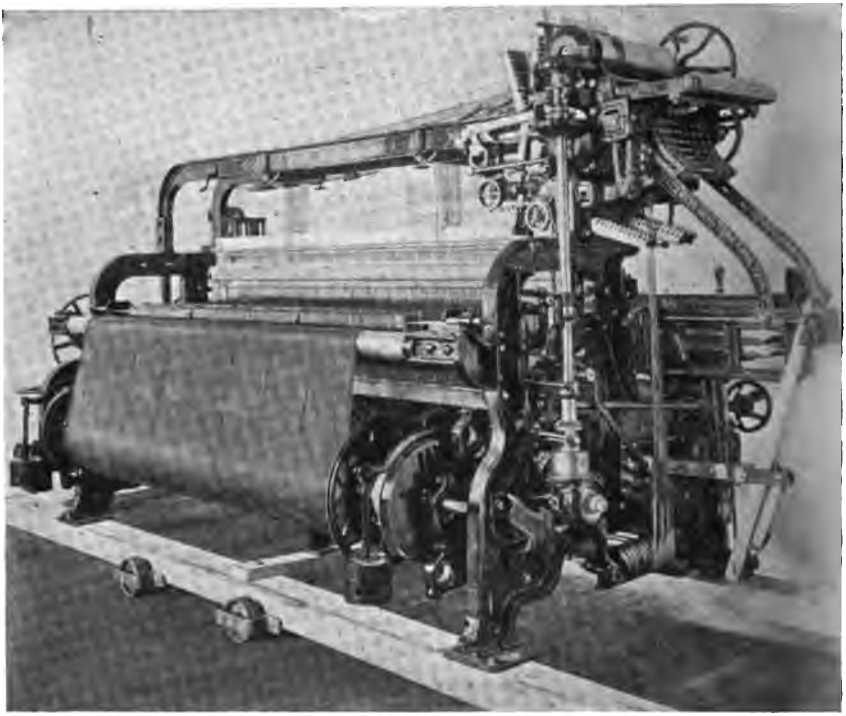

Fig. 34. Sec. 10*rr*.—Back view of automatic heavy worsted loom.

LUBRICATION.—These cuts clearly show the type of lubrication met with in this class of machinery. A medium-bodied engine oil is suggested for use on these machines, as follows: For worsted, cotton, or woolen looms, plain and fancy types, 260 to 300 Vis. at 100° Fahr. (P. B.), 350 to 450 Vis. at 100° Fahr. (A. B.). For use on gears, a cup grease of No. 3 body is recommended. For general lubrication, a semi-fluid lubricant of five-eighths the consistency of vaseline is also recommended.

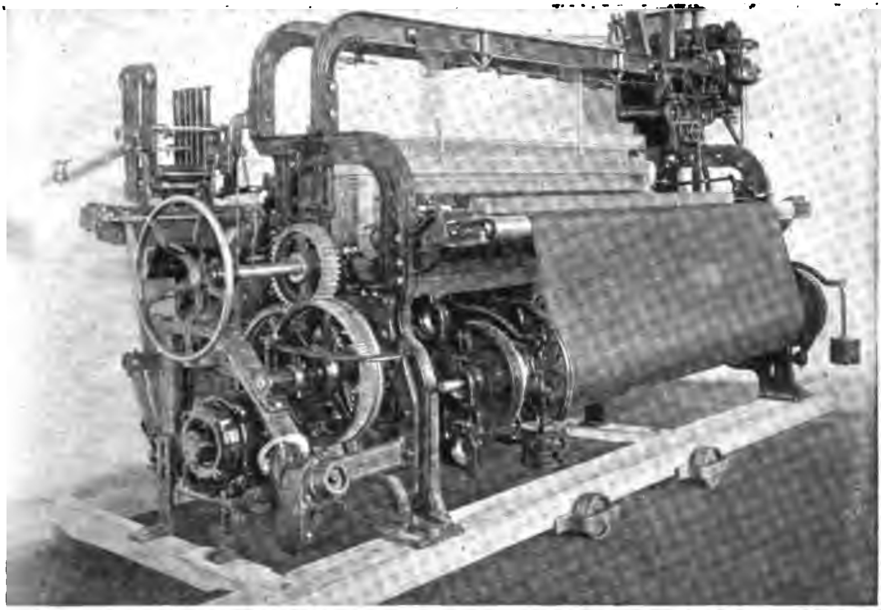

FIG. 35. SEC. 10rr.—Back view of automatic heavy worsted loom.

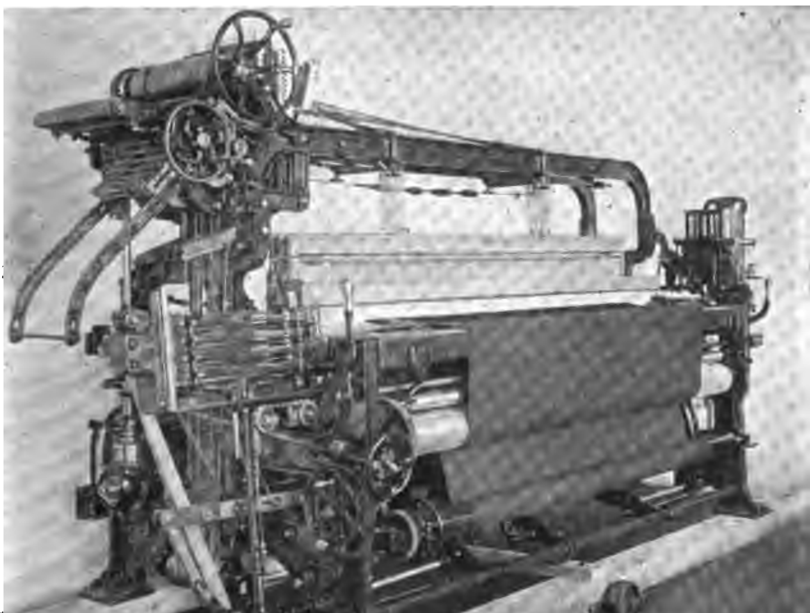

FIG. 36. SEC. 10rr.—Front view of automatic heavy worsted loom.

KNITTING

The general operating principle of the various makes of knitters of the automatic type is about the same. This principle is to catch the yarn under the hooked end of the needles and to then draw it down and loop it into a chain stitch with the aid of horizontal sinkers. These needles and sinkers are actuated by means of cams, which are placed in a suitable position and mounted in a "cam ring," in the case of circular types of knitting machines.

The two general types of knitting machines are the circular and the flat knitters.

One of the important factors of knitting-machine lubrication is that a lubricant must be used which has a low rate of evaporation, and which at the same time should possess as high as possible the property of adhesiveness. This is to prevent dripping and spattering. The lubricant should be sufficiently free-flowing to feed through a capillary wick, and must be as stainless as possible. It should have no tendency to gum.

In the average mill, using oil lubrication, there is from 10 per cent. to 12 per cent. of "spoilage," due to oil stains caused by creeping and dripping of the lubricant. The general practice seems to be to make up about 10 per cent. more hosiery than ordered, in order to allow for "returns," or "rejects." In the case of cotton and lisle hose, these "rejects" can be dyed black. Silk hose can also be black-dyed, but at a slightly higher cost than for the cotton and lisle. In the case of artificial silk hose, these "rejects" are more or less of a total loss, because when artificial silk is wet, it is very weak. In the case of embroidered hose that has become oil stained, it is practically a total loss, because it is usually embroidered in contrasted colors, and on redying this contrast is lost.

It is well known that the stains on fabrics are not due so much to the oil itself, but rather to the metallic grindings or wear from the bearings which are carried into the fabric with the lubricant. Tests have demonstrated that stains caused by oil and metallic wear cannot be successfully removed, and while it is desirable to use a lubricant that will to some extent wash out, nevertheless the best rule to follow is to select a lubricant which, while filling the lubricating requirements of the equipment, at the same time possesses a strong characteristic of non-spattering and non-dripping.

FULL-FASHIONED KNITTERS

The "full-fashioned knitter," or "flat knitter," is a multiple-head machine; that is, consists of 18 to 20 sections in one machine. Each section produces a stocking and is really a knitting machine in itself, except that it shares with the other sections the drive-shaft motion, tension, take-off, and narrowing motion.

The name "full fashioned" means that the product of the machine is fashioned on the machine after the shape desired. In the case of hosiery, the shape follows that of the human leg. The production of women's hosiery is divided into two operations. The leg is made on a machine called a "legger" and the foot of the stocking is made on a machine called a "footer." Leggers are very much alike as to operating principles, differing only in width of their heads and in the narrowing motion.

The full-fashioned machines have gears, cams, long drive shafts, and cam shafts, tight and loose pulleys, slides, sinkers, chains, screws, and rackets, which require lubrication.

In the lubrication of the full-fashioned machine, as in the case of the circular knitters, a lubricant must be used which has a minimum tendency to creep and spatter onto the fabric. The slides should be lubricated with an oil having about 375 Vis. at 100° Fahr. A No. 3 cup grease should be used on the gears and cams. A well-filtered oil of lighter viscosity can be used with success on the other parts of the machine.

It should be borne in mind in connection with the lubrication of these machines, that the most important factor is to keep the lubricant from dripping or throwing onto the fabric. The stain in a fabric is caused by the metallic particles carried onto the fabric from the bearings and slides, and tests have demonstrated that "metallic wear" carried onto a fabric by the oil cannot be successfully removed by scouring, and while it is desirable to use a lubricant carrying any percentage of compound to improve its washing-out characteristics, particular care must be exercised to avoid excess lubricant and dripping and throwing.

CIRCULAR KNITTERS

AUTOMATIC SEAMLESS HOSIERY MACHINES.—In general, the various makes of automatic knitters employ the same principles of operation, which is to catch the yarn under the hooked end of the needles, and to then draw it down and loop it into a chain stitch, with the aid of horizontal sinkers. The needles and sinkers are actuated by means of cams, which are placed in a suitable position and mounted in a cam ring. in the circular types of machines.

In the "circular type of knitter," the revolving needle cylinder, made of brass or bronze, is slotted to hold as many needles as the fineness of the hose demands. The cylinder is vertically mounted in a "cam ring," made of steel, and it is driven by means of a beveled gear, which is mounted on the main cross-drive shaft. The drive shaft, the change-speed shaft. the clutch drum, the pattern-drum shaft are horizontally mounted in a cast-iron frame. Generally those shafts turn in brass bushings equipped with oil grooves and oil holes. The yarn is brought to the machine wound on paper cones, and is placed on spindles on the yarn rack. The number of cones used depends upon the class of work being turned out. From the cones, the thread is led through porcelain dies upward, and then down to the thread feeders, or yarn changers, which are levers provided with eyelets in the ends, through which the yarn passes. These fingers feed the yarn over a polished plate, which is known as the "throat," to the reciprocating needles.

These needles, as they make their downward stroke, hook the yarn and draw it down, where it is held by sinkers. The next course is then drawn down between the loops by the preceding course, etc.

The yarn changers, or thread fingers, are controlled as to their motion by means of wires, which lead down to the cam levers, which are actuated and held steady by means of a set of cams located on the cam shaft or drum. The cam drum is turned or steadied by means of a ratchet and pawl. This is so arranged that the pawl may either engage and turn the drum, or it may disengage and allow the drum cams to actuate the connecting rods. A constantly moving pattern chain controls this movement, the chain being furnished with lugged links at the proper intervals, which bring into operation the different movements as they are required. The lugs control the pawl, by holding it off the ratchet, or permitting it to engage, as desired.

In order to produce the small diameter and double plaiting of the heel, foot, and toe, provision is made for automatically shifting the driving belt to a change-speed pulley, which has mounted on its shaft a shifting gear, which moves the cylinder back and forth through a number of degrees of a circle, this motion being obtained by means of a moving quadrant and pinion. There is a clutch that by alternately engaging and freeing the driving gear gives the quadrant motion.

The speeds of the main drive shafts are usually never higher than 300 R. P. M. The parts of the machines are light in weight and the bearing pressures are low. There are gears to be lubricated, cams, etc. However, these parts do not require a very viscous lubricant.

It has generally been the custom on these machines to use two oils. One oil, a high-grade lard oil, or a highly compounded petro-

leum-and-lard oil, for the machine lubrication. The other oil, usually a vegetable or special proprietary oil, for use in the capillary cups, which are provided with a wick, which syphons up the oil. This wick is hung over a small bar, at the top of the cup, or it may consist of a pad under a small regulated orifice, through which the oil is dropped onto it. The yarn is passed over this wick, or pad, for the purpose of wetting it and laying the fibres, and also to give some lubrication to the needles, particularly for the needle latches.

One of the most common troubles met with in the case of the yarn lubricant is the likelihood of excess lubricant on the needles, causing black needle marks in the toe seams and gussets. It is the custom in many mills to turn their after-oiling output into black.

One of the most successful lubricants for these machines, and which may be used for both the lubrication of the machine and the lubrication of the yarn, is a very light white grade of semi-fluid lubricant of about one-eighth consistency of vaseline.

A light oil of about 145 Vis. Say. is sometimes used for lubrication when a separate oil is used in the oil cups. Some mills use a "stainless oil" made of a filtered spindle oil and 10 per cent. to 20 per cent. of lard-oil compound.

Fig. 37, Sec. 10rr, shows an automatic seamless hosiery machine, made by the Scott & Williams Co.

HOSIERY.—There are several kinds, called cut goods, seamless, or full-fashioned.

"Cut goods" are made of round webbing, knitted on a circular machine. The web looks like a long roll. First it is cut off to stocking length, and it is then shaped, by cutting out and sewing up, or it may be shrunk. It is next slit for the insertion of the heel, and the heel is sewn in. The toe is now put in. The hose is then scoured, dyed, and shaped.

"Seamless hose" is made on the same machine. The toe piece is left to be joined by the "looper." The ankle is made the same size as the calf, and to remedy this, the hose is steamed and shaped on boards.

Fig. 37. Sec. 10rr.—Automatic seamless hosiery machine.

"Full-fashioned hosiery" is produced by means of expensive machines, which automatically drop the requisite number of stitches at the ankle, to shape the leg. The toe is produced in the same way, also the shaping of the heel and "gusset."

Full-fashioned hosiery is made on several machines. One makes the leg to the foot, one knits the foot, next the "looper" stitches the heel and toe together. The hose is then dyed, "boarded," stitched and dried, and finally heated and pressed.

FULL-FASHIONED UNDERWEAR.—This class of underwear is knit flat and then sewed together.

"Plain knitters" produce plain fabrics only, and "ribbed machines" make "ribbed fabrics." Therefore, half hose, or underwear with cuffs, must have the ribbed parts knitted on one machine, and then the piece is transferred to a plain machine to be finished.

SPECIAL TEXTILE PLANTS

CARPET MILLS

Carpet looms in general are the heaviest type of loom for weaving; that is, the cranes are substantially built. They are also very intricate.

A carpet loom has a hard, quick and perpetual motion and bearing force and weight at all times. It has a varying speed of 100–200 picks. In order to lubricate properly, an oil of a suitable body should be used to save wear and preserve the accuracy for which the loom was built, or constant stopping occurs and fixing is required.

On the gears that are subject to great vibration, due to the force of the lathe, a good grade of grease should be used, or a heavy semi-fluid grease. In the bearings of the shaft, on which the gears are held, a grade of oil of about 200–250 (P. B.), or 350 (A. B.), should be used. These gears carry the power for the eccentric shaft, that moves the lathe back and forth.

The lathe tacks the filling in the carpet, or the pile, generally known, and holds it tight, while the harness changes the position of the warps and binder that interlace the pile, or filling. On the harness bearing, working by cams, an oil of the same tests as above should be used, as there is much tension, or weight on the harness.

The method of oiling carpet looms at the present time is to use cheap loom oil, and plenty of it, as there is much oil lost, due to the vibration and constant stopping to change shuttles and tie up broken warp threads. The oil is so light that it is whirled off in motion and drips off when the loom is stopped. On the loose pulleys, generally grease cups are supplied. A No. 3 cup grease should be used; also where the loom works with a friction clutch, where in the average case is found grease cups, use No. 3 grease.

The floor of the average weave shed is continually wet with oil.

The 3/4, or 27-inch loom, of course, has more vibration than the broad loom, as the latter is a heavier loom, which can hold its own when it is working with the same force but a little faster speed, but the conditions exist here the same as described above.

The drawing wires on carpet looms require lubrication, to assist in the drawing out of the wire from the pile, or loop. These wires are about 1/8 inch in diameter. Some are equipped with a fin-shaped knife on the end, which is intended to cut the loop, or pile, as it is withdrawn. Plain wires are used only when the pile, or loop, is not cut.

Carpets are marketed direct from the loom, without washing or scouring. Manufacturers prefer a pale oil, or a so-called stainless oil, or a stainless grade of semi-fluid lubricant. Some manufacturers use straight lard oil for this purpose.

For this lubrication use an oil of 150–160 (P. B.).

For dyeing machinery, warpers, quillers, beaming frames, spoolers, looms, sewing machines, etc., such as found in these mills the general lubrication is as recommended for these machines under separate headings.

The machines are comparatively slow moving. When working on heavy carpets and rugs humidifying systems are used.

AUTOMOBILE TIRE FABRIC PLANTS

These plants contain usually the following machines: Cards, draw frames, slubbers, twisters, spoolers, warpers, splitters, looms, etc.

The yarn is of a coarse, heavy variety, as the fabric desired is heavy and closely woven. The machinery is of heavier construction than is found in the usual cotton mills. The goods are not scoured or washed, but are marketed from the looms. They must be free from oil.

For the general lubrication use the lubricants recommended for the various machines in other sections, but a good general lubricant would be of an oil of 240 Vis. (P. B.), or 350 Vis. (A. B.), or semi-fluid lubricant five-eighths consistency of vaseline.

HOSE MANUFACTURING PLANTS

Braiding machines, in the braiding between the several layers of vulcanized rubber, are somewhat like circular rib knitting machines, without the use of the needles. They have a speed of about 300 R. P. M. Oil stains are not important. The braiding resembles a plaited formation of cotton yarn when finished.

For general lubrication of these machines use oil of 240 Vis. (P. B.), or 350 Vis. (A. B.), or semi-fluid lubricant of five-eighths consistency of vaseline.

PRINT WORKS

In the manufacture of printed goods, such as cretonnes, shirtings, dress goods, etc., the following machines may be used: Warping machines, dyeing machines, whizzers, calender rolls, bleaching machines, mercerizing machines, engravers, stocks, printing machines (see Fig. 38, Sec. 10rr), singers, folding machines, etc.

FIG. 38. SEC. 10rr.—Printing machine.

These machines are not fast running, and require only a medium viscosity oil.

Humidifying systems are used to keep down the temperatures and liven the goods and colors. As a rule, no looms are operated in print works. The goods are received in the piece, in the white, unbleached state.

Printing is done after bleaching, and the main requirement is a lubri-

cant with sufficient body and non-throwing characteristics to prevent any lubricant getting onto the goods. The absence of oil stains is important, as the goods are marketed direct from the printing machine, without any further finishing except from the singer.

For the gears of printing machines etc., use a No. 2 pinion grease.

For general lubrication of the machines use 240 Vis. (P. B.), or 350 Vis. (A. B.), or a semi-fluid lubricant of five-eighths consistency of vaseline.

QUILT MILLS.—These mills usually contain carding machines, garnetting machines, automatic quilt sewing machines, lappers, etc.

The machines are not fast running in general. The fancy roll of the garnetting machine has a speed of about 2000 R. P. M., with a 1 15/16-inch shaft. This bearing should be lubricated with a No. 3 cup grease, as the bearing usually runs at about 180° F. to 200° F.

For general lubrication use an oil of 240 Vis. (P. B.), or 350 Vis. (A. B.), or a semi-fluid lubricant of five-eighths consistency of vaseline.

TAPESTRY AND PLUSH MILLS.—The equipment found in these plants may consist of warpers, gassers, spoolers, quillers, beaming frames, loopers, finishing machines, calender rolls, shears, bleaching machines, folding machines, etc.

These machines are not fast running or heavy. The lubricant should be of such a character that it will not throw onto the goods. The goods are scoured and bleached in the white, and then dyed. If there are any oil spots they will dye over. On casket work and high-class upholstery work, the goods are scoured by hand, with a gasoline solution.

For lubrication use the general recommendations as given under other sections for this class of machinery.

TAPE LOOMS.—Tape looms are very light-running machines. They weave 60 to 70 bands at a weave, with a speed of about 200 picks per minute. A pale oil is preferred by the trade, or a semi-fluid lubricant of the stainless type. The tapes are marketed direct, without washing or scouring.

For this lubrication use oil having 180–200 Vis. (P. B.), or 250 Vis. (A. B.), or three-eighths consistency semi-fluid lubricant.

TURKISH TOWEL MILLS.—Turkish towel looms are light running and high speed. They average about 100 picks per minute. Manufacturers prefer a pale oil, owing to the fact that the finished product is marketed direct, without scouring or washing. A light grade of semi-fluid lubricant is also used with success.

For this lubrication use same as above.

EMBROIDERY MACHINES.—Fig. 39, Sec. 10rr, shows an embroidery machine equipped with a Loeb & Schoenfeldt automatic control. A semi-fluid, three-eighths consistency lubricant, or an oil of 180–185 Vis. (P. B.), or 200 Vis. (A. B.), is recommended.

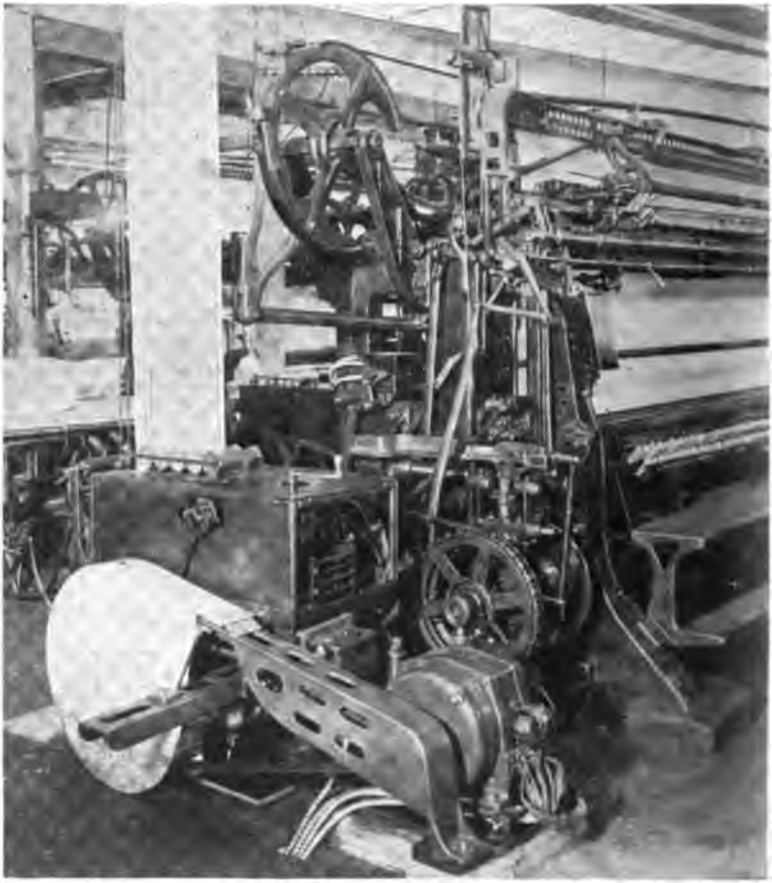

FIG. 39. SEC. 10rr.—Embroidery machine with automatic control and G. E. motor.

FULLING MILLS AND CLOTH WASHERS.—The rolls of these machines are often subjected to uneven feed. The tension springs bend under constantly changing loads.

In some cases soapy drippings, or water, may reach the bearings.

For the lubrication of bearings of the plain type either grease or oil

may be used, and in those machines that are equipped with ball bearings use a neutral No. 1 grease.

DRYERS.—A fan is used to circulate the air in the dryer, and its careful lubrication is important, as the efficiency of the drying of the stock and yarn depends upon the proper circulation and exhaustion of the air in the dryer.

If the goods in the dryer are inflammable, the machine must operate with cool, easy-running bearings, and there must be no throwing or leaking of lubricating oil from the bearings. Sometimes the accumulation of lint, or dust, on the bearings acts as a wick and draws the excess oil up, causing the fabrics to be soiled and increasing the fire risk.

In some types of dryers the bearings are mounted upon pillow blocks, which are bolted to the dryer frame; in others, the fans are mounted upon

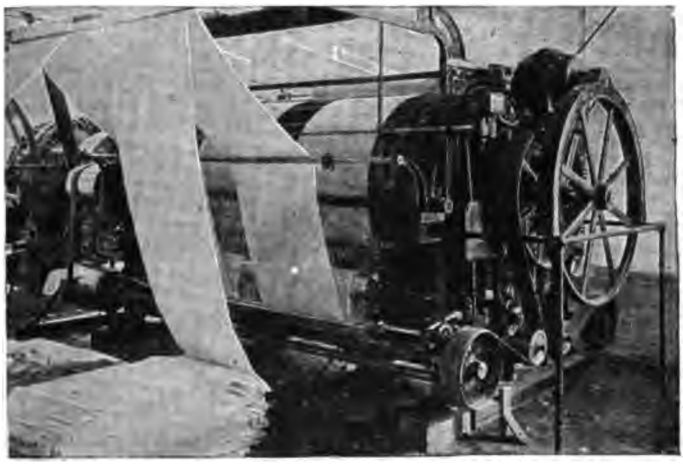

Fig. 40. Sec. 10rr.—36 roll double action napper, showing driving end. Equipped with S. K. F. ball bearings.

hollow tubing, which extends through the drying chamber and is supported by a bearing at each end. Another method is to attach the fan to a hollow tube that runs on ball bearings and extends through the dryer.

The fan must keep a large circulation of heat in motion. It is important that the fan bearings be well lubricated to prevent excessive wear, since, if the bearings become worn, and vibration starts up, the metal sides of the dryer being of sheet metal, quickly take up the vibration and the dryer will run very noisy. There is also a possibility of causing the shaft to crystallize at the point where the main vibration occurs.

Many makes of dryers are now equipped with ball bearings, and this marks a great improvement in this type of machine, resulting in a considerable saving in power, and a reduced possibility of soiled fabrics.

For the lubrication of fan bearings of the plain type, where oil cups are provided, use an oil of about 275 Vis. (P. B.), or 350 Vis. (A. B.), or a semi-fluid lubricant of five-eighths consistency.

For ball-bearing dryers use a semi-fluid lubricant of seven-eighths consistency.

NAPPERS.—The "worker rolls" of nappers undergo severe service. These rolls may revolve at speeds of from 1000 R. P. M. to 1500 R. P. M., and as they have considerable length, there is always a tendency to "whip." The belts on these workers are kept very tight, and, as a consequence, there is a considerable bearing load.

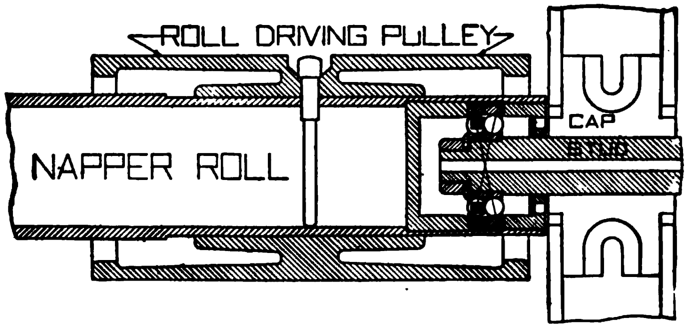

FIG. 41. SEC. 10rr.—S. K. F. ball-bearing mounting on napper roll.

The main drum also has a bearing requiring careful lubrication. The bearings on nappers are subject to great wear, and must be carefully lubricated. Roughly, it requires about 6 H. P. to drive a 36-roll, 80-inch napper, using 8-inch belts. Ball bearings are used on the most up-to-date machines.

For the lubrication of the worker ball bearings and the main cylinder bearings, use a No. 1 or No. 2 cup grease that is free from any free acid or alkali.

Fig. 40, Sec. 10rr, shows a double-action napper, from the driving end.

Fig. 41, Sec. 10rr, shows a ball-bearing mounting for a napper roll.

SILK.—Silk fibre, as spun by the silkworm, consists of two portions: the fibre, which is the interior portion, and the "gum," which is the exterior portion. This gum may run from 25 per cent. to 35 per cent. of the total fibre. To obtain the full lustre of the silk fibre, and to make the fibres soft, the gum is removed by two or three boilings in a soap solution. The first boiling is generally known as "stripping," and the second as "boiling off." The soap liquor from the boilings is called "boiled off liquor," and it is later used in the dyeing of the silk, with coal tar colors. Olive oil soap (soft or hard), castor oil soap, etc., are used. The last portion of the silk glue or gum is usually taken off by washing in a water containing some soap and some sodium carbonate; the bath being at about 140° Fahr.

The silk is put into bags of coarse material and boiled for a length of time, depending upon its quality.

SILK OIL.—In the use of silk oil, it is usually mixed with hot water to form an emulsion. The proportions are about one quart of oil to a gallon of water. A typical silk oil is made by compounding a filtered spindle oil with extra white neatsfoot oil. About 25 per cent. of the neatsfoot oil is blended with 75 per cent. of an oil having the following general tests: 135 Vis. at 100° F., 30° B. Grav., 395 Flash.

USE OF SILK OIL.—An emulsion is made with one gallon of hot water and one quart of silk oil, as above described. Then 12 to 16 ounces of olive oil soap is mixed in a pail of water. About a gallon of the hot water is used, and the soap is allowed to dissolve. Next, both the emulsion and the soap water are put into a small vat, which has a steam pipe in it, extending nearly to the bottom. About a one-inch pipe is used.

The vat is then filled to about one-third of its capacity with cold water, and steam is turned on until the mixture reaches a temperature of about 212° Fahr.

Next cold water is run into the vat until it is filled to about two-thirds of its capacity, and this mixture is heated to about 70° Fahr.

The skeins of silk are put into muslin bags and are allowed to soak in the mixture for about 8 to 10 hours. The silk is then taken out and put into an extractor for a half hour. The extractor is operated by steam, and is designed to remove the excess emulsion and silk gum. The silk is now in a damp condition.

The silk is next taken to the dry room, where the skeins are separated and dried. It remains in this room for about five or six hours.

The silk is now ready for the throwing department, to which it is taken.

The vat used for the emulsion has the following general dimensions: 30 x 30 x 36 inches.

In one plant, for each 100 pounds of silk, 5 pounds of olive oil soap, and 3 quarts of neatsfoot silk oil were used.

SILK SOFTENER.—Silk contains a kind of gum when in its raw state, and before working this into a fibre for weaving, knitting, etc., this gum must be removed.* This is done by placing the silk into a tank and water added. Then from 2 per cent. to 5 per cent. of boiling-off oil is added. This is usually a form of Turkey red oil, or sulphonated castor oil. The silk, water, and oil is then boiled, and the silk will split and swell up, releasing the gum. Some manufacturers use corn oil, cottonseed, or even resin oil in this "degumming," or boiling off of the silk. Portions of the oil containing the oil gum are run off and stored in tanks, and portions of this are added to the dyeing bath, when again more oil is used to bring the dyeing bath to the proper strength.

The object of the silk softener is to make the fibres of the silk soft and pliable and less liable to break. Silk must be soft, and still have a crunch, or crackle, to it. Among the oils used are Turkey red oil, sulpho-castor, soluble castor, or liquid soap, monople oil, etc.

For knitting, the solution is placed into a tank and a covered roller takes up small quantities of the oil, as the fibres of the silk run over the roller, particularly for full-fashioned machines. The solution is made in various proportions, and must be free from anything insoluble, so that no particles of a soapy substance can remain on the goods. On knitting machines they use a cup feeder, which slowly feeds, by means of a wick, against which the thread runs.

Silk softener is used extensively in the mercerizing process, as well as in the silk industry, to make the thread soft after mercerizing, and at the same time have a crunch, or crackle, to it.

One formula used for making silk softener is as follows:

73 gallons of Turkey red oil.
21 gallons resin oil, or corn oil.
8 3/4 gallons of water.
1 1/2 gallons of red elaine.
2 gallons soda water, made with 1 3/4 pounds of soda to 1 gallon of water.
3 ounces of citronella.

This solution can be boiled in water without breaking down. A softener that breaks down in boiling is of no use for softening purposes.

EFFECT OF GASOLINE VAPORS.—The *Textile World Journal* says: It is probable that gasoline vapor alone has no action on the colors of dyed silk, but if the vapors are allowed to condense, then the solvent action of the gasoline will become manifest and the dyeing will become shaded. Many shades dyed upon silk are produced by means of basic dyes. the chemical bases of which are soluble in hydrocarbons.

* See page 987.

SILK MILLS.—There are about 1875 silk mills in the United States, the greatest number being in New Jersey, and the second greatest number being in Pennsylvania, while New York is a close third.

SILK SPINDLES.—A 200-spindle frame, running at 15,000 R. P. M., requires about five horse-power. The power consumption of plain-bearing spindles increases as the square of the speed.

Ball bearings are in use in many plants. Speeds as high as 20,000 R. P. M. are obtained.

In general spindle speeds are about 13,000 R. P. M. for plain bearings, and 17,000 for ball bearings. If the driving belts become stretched, or oily, slippage occurs. This decreases production and impairs the "twist." Care must be exercised in the selection of a lubricating oil and its application to prevent throwing.

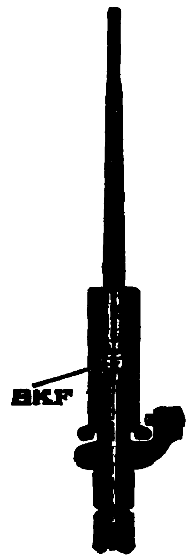

FIG. 42. SEC. 10rr.—Silk spindle with section cut away to show ball bearing.

The S. K. F. Ball Bearing Company report the following test on an Atwood spinning frame, second-time spinners, 86 spindles per frame. One set was equipped with plain bearings and the other with S. K. F. ball bearings:

Spindle Speeds (R. P. M.)

	Average actual speed	Theoretical speed	Slip average	Per cent. slip
Plain-bearing (set)	9,275	10,670	1,395	13.0%
Ball-bearing (set)	10,425	10,670	245	2.3%

Power per frame of 86 spindles, watts	Power per spindle, watts
Plain bearings, 1,084 at 8,480 R.P.M	12.60
Ball bearings set 796 at 10,425 R.P.M	9.25
Difference	3.35 watts per spindle

Fig. 42, Sec. 10rr, shows a silk spindle from an Atwood machine, with section cut away, showing the ball bearings.

NOTES ON SILK

STAINS ON SILK FABRICS.—From time to time stains on silk fabrics will be brought to the attention of the industrial oil engineer and textile specialty man, and the following information may prove of value:

Certain silk goods, especially weighted taffetas in delicate shades, may develop spontaneous stains in storage. Sometimes these stains are mere spots irregularly distributed over the fabric, and sometimes they are quite large. In some cases the stains are only on the weft, and then again they may be only on the warp.

Investigations that have been made seem to indicate that these stains were due to perspiration, which had been transferred from the hands of the operator during manufacture. This is probably the case for small stains, but in the case of large stains covering considerable surface, investigators have concluded that common salt is the cause. Salt being an essential element of perspiration, the stains are due to this product. Salt may be brought into contact with the fabric also by neglect of the operators to wash their hands thoroughly after eating, or from the fingers of snuff users and cigarette smokers.

Reports have been made of experiments in which it was shown that silks, especially weighted silks, undergo destruction in the course of 12 months, if charged with 5 per cent. of salt, by weight. One per cent. of salt produces pronounced tendering in two months, while in summer 2 per cent. to 6 per cent. in seven days.

The weighting agents, such as oxide of tin, tin and alumina, and silico-phosphate, do not seem to be directly connected with the deterioration, but their presence may make the progress quicker than would be the case with pure silk.

Dyestuffs most sensible to oxidation are most readily affected and stained. The lighter the shade the more rapid the change. The action of salt is shared in a smaller amount by the action of the chlorides of ammonia, magnesium, calcium, barium, zinc, potassium, and aluminum.

Some weavers use soap to size the warp, or may keep the silk in bags, moistened with soapsuds. These soaps contain salt.

ARTIFICIAL SILK.—Cellulose, usually in the form of cotton fibre, is the starting point. The spinning is effected by forcing a very viscous fluid through fine orifices of glass or metal. The collodion process filament (Chardonnet Process) solidifies quickly on forcing out of the jets; the Cuprammonium process has the material from the spinning jet delivered into a solution that decomposes it and liberates the cellulose, which will form a filament, becoming stronger as the water leaves it; another process is effected by spinning the filament into a solution of ammonium chloride to cause a separation of the cellulose of the filament. Artificial silk loses strength on wetting. Natural silk is higher in nitrogen than artificial silk, which contains only a trace. Heating artificial silk to 200° C., when mixed with other fibres, destroys it.

TEXTILE PRODUCTS

TURKEY RED OIL.—Castor oil, due to its property of forming a soluble soap in conjunction with a minimum amount of alkali, rather than an emulsion, as do the other fatty oils if the alkali proportion falls below the amount required for complete neutralization, is the most suitable for use in connection with Turkey-red dyeing.

"Commercial Turkey-red" oil is less viscid than castor oil, and in color resembles it. It should mix freely with water in any proportion. Generally this oil is sold as containing 33 per cent., 50 per cent., or 70 per cent. of water. It is a sulphated castor oil.

This oil is used in the dyeing and printing of Turkey and alizarine reds on cotton, and in other similar dyeing operations. It tends to increase the brilliancy of the colors.

In the manufacture of this oil, practically every manufacturer has his own special methods, but in general, castor oil of good quality is mixed in a vat with strong sulphuric acid and allowed to stand, and after about 24 hours about the same amount of water as there was oil is stirred into the oil until a uniform mass is obtained. It is then again allowed to stand until separation has occurred, the oil being on top and an aquaeous mixture at the bottom. The acid mixture is run off, and, after washing the oil to remove as much of the sulphuric acid as possible, a solution of caustic soda is slowly poured into the acidified oil, while the mixture is constantly stirred. The mass first turns creamy, then streaks appear, and as the caustic solution continues to be poured slowly in the mass, it becomes clear and transparent. Then water is added as desired.

In the past, olive oil, known in some parts as Gallipoli oil, was used for the same purpose.

SOLUBLE OIL FOR FINISHERS.—This is usually a solution of a castor-oil soap, and is intended to give a soft feel to cotton cloths. The castor-oil soap can be made by boiling good castor oil with a small amount, say, about one-eighth of its volume of water, in which has been dissolved caustic soda.

The resulting castor-oil soap is a clear soap paste. When this soap is mixed with clear water the solution is ready for use. The castor-oil soap will give a straw-colored, soluble oil, while the other fatty oils give a dark oil.

SOLUBLE OIL; USES OF.—The name "soluble oil" is generally given to a product obtained by treating castor oil with sulphuric acid, washing and partially neutralizing with soda, or ammonia, as above described.

If the neutralization has been complete, the oil contains some water, and will mix with water, forming a clear solution. In case the neutralization has been incomplete, an emulsion will be formed.

Some of the uses for the clear solution, as above described, are boiling off silk, and cotton goods; also in wool scouring. Generally the emulsion, as described, is used as a softener.

Generally these soluble oils have good emulsifying properties, and are capable of causing larger quantities of other oils to remain in suspension in water, and for this reason are often used as a basis for cotton softeners, and sometimes for silk throwers' emulsions.

Either the emulsion form, or clear form, may be added to a direct cotton or a silk-dye bath. During the dyeing operation the fibre absorbs some of the oil, giving better softness and improving the lustre.

* **SILK SOAP.**—When the silk fibre, as spun by the silkworm, is received, it is formed of two portions, the inner portion, or silk fibre, and the outer portion, called the gum. To get the desired lustre to the silk, this gum must be removed, and this is done by successive boilings in a soap-and-oil solution. The soaps that are best for this purpose are those made from olive, lard oil, etc., giving soaps that are readily soluble in water.

The boilings are usually two in number, and the first solution is a little stronger than the second.

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* See page 987.

OIL STAINS

KHAKI; OIL SPOTS AND REMOVAL OF.—Some plants use gasoline on the oil spot and then spread Fullers' earth over the stain. This process is not so good, because of its slowness, and due to the fact that it tends to soil clean goods.

If the oil spots are unevenly distributed, the goods may be run through equipment containing gasoline. In some cases, where the color of the goods is fast, results have been obtained by moderately soaping with a weak soap liquor and then washing.

Carbon tetrachloride, while expensive, is a good oil solvent, and is not inflammable.

REMOVAL OF OIL STAINS FROM FABRICS.—Many firms have their goods inspected for large oil stains, and remove them by "hand scour" before putting the goods into the scouring machines. Goods that are run in a scouring machine are generally worked from one to two hours, according to the amounts of stain and foreign matter contained therein. If the scouring solution is properly mixed, there should be no difficulty in removing "small stains."

One of the largest scouring and bleaching firms in Philadelphia use the following formula with great success: In a tank 12 feet long and 5 feet deep, filled with water, put 2 barrels of good textile soap, containing about 1 per cent. alkali, and add to this two (2) barrels of soda ash. A soap that is working properly should develop a fine creamy lather on the water. It should not be allowed to get pasty or too thick.

If the above formula is used, there should be no trouble in removing small stains from the goods in the scouring machine. The large-sized stains should be scoured out by hand.

A large oil stain on a knitted fabric may be hand-scoured in the following solution: Three and one-half ounces good textile soap, 4 ounces ammoniated soda (which is 3 ounces ammonia water and 1 ounce sal soda, or soda ash), and one (1) gallon of water. The stain can be removed in about a minute by this method.

KEROSENE; REMOVAL OF FROM FABRICS.—One method of removing kerosene from fabrics is to pass the fabric over a heated "tenter frame," or through a dry room. In some cases, passing the fabric over a set of heated cans will be successful. Fabrics passed through a steamer at low pressure will usually remove the stain and the odor. Stretching the fabric on frames, in the sunlight, giving free access of air to all parts, will usually effectively remove the stain and the odor.

TEXTILE NOTES

DYED YARN; LUBRICATION.—In order to make yarn run smoothly through the needles, paraffin wax may be used for lubrication. This can be used with those yarns which will not stand washing. Two discs of paraffin can be made by running the wax out into a pan to about 3/8-inch thickness, and then cutting out with a tin ring, as desired. A sleeve over the spindle, with a narrow bearing on each end to reduce friction, should be provided. The holes in the wax discs should be just large enough to pass over the sleeve. A tin disc must be provided on each side of the paraffin disc, to act as a bearing for the springs, keeping the paraffin disc pressed against the yarn when passing through. The wax discs can be used instead of the ordinary tension discs on the winder.

EFFECT OF OIL ON TEXTILES.—In order to determine the effect of petroleum oil on textiles the following tests were made: Samples of pure cotton, pure wool, pure silk, and surface-treated leather were immersed for a period of 60 days in a light neutral oil of about 145 Vis. and 30 1/2 B. gravity, and also in a light paraffin oil of about 27 B. gravity and 175 Vis. After being immersed in these oils for 60 days, the samples were removed from the oil and naphtha washed to remove the oil.

It was found that the strength of the samples was about the same as before the test, the colored parts of the fabric retained their original color, and the white parts were slightly dirty; there seemed to be no difference between the samples immersed in the paraffin from those immersed in the neutral oil.

WATER-PROOFING CANVAS.—The following information regarding the water-proofing of canvas was contained in an article by Mr. E. R. Clark, and printed by the *Textile World*, May 18, 1918: The cloth before water-proofing should be of such construction as to reduce to a minimum the probability of the finished fabrics showing pinholes or reed marks. Practice in dyeing differs. Where the water-proofing is done from a melted mixture, probably the incorporation of the pigment in the melt is the most suitable process. For the metallic soaps of water-proofing, the use of sulphur dyes is more general. Mr. Clark has classified the various processes of water-proofing as follows:

1. The aluminum-soap process.
2. The asphaltum, paraffin, pitch, etc., methods.
3. Processes involving the use of two fabrics.
4. Cuprammonium and other processes based on dissolved cellulose.
5. The drying-oil methods.

"*The Metallic Soaps*": On the metallic side the aluminum compounds seem to be established as the best. Basic aluminum acetate is the most frequently used salt. Aluminum soaps made from aluminum acetate and saponified linseed oil are especially desirable. The fabrics prepared by this method have shown good water repellant surface, but have been found to permit the passage of water under severe conditions. The process has been shown to have value for clothing materials.

"*The Asphaltum Methods*": The best materials have been those where the water-proofing was accomplished by the use of a waxy material having

suitable properties as regards melting and hardening points, and permanence under service conditions. Asphaltum is a good material, as it can be applied melted and does not require dissolving. Paraffin is widely used, but it has the tendency to become brittle and favor mildew growths. For the purpose, a low melting-point paraffin is used.

Resin is sometimes used, but is not staple enough for the purpose, decomposing readily in the light and not yielding a water-proof surface. Resin is sometimes mixed with petroleum to give the desired consistency. Wool grease is sometimes used. However, the waxy material used should resist emulsification. Resin does not prevent the growth of mildew.

Rubber mixed into melted paraffin is sometimes used for impregnation. Canvas water-proof with the waxes is usually greasy and adds weight. The waxes lend themselves easily to the incorporation of pigment.

"Duplex Cloth": This process usually covers the use of a central coating of some adhesive substance.

"The Cuprammonium Process": This process depends for effectiveness upon the partial solution of the fibre, followed by its precipitation as a continuous film.

"The Drying-Oil Process": Drying oils are not in favor, due to their tendency to spontaneous combustion and poor permanency and service conditions. Linseed oil and substitutes, with the property of formation of a film are used. These films are objectionable, in that they are likely to crack.

Notes.—The aluminum soaps can be hydrolized readily and removed from the fabric by boiling a sample in dilute hydrochloric acid. The fatty acids will separate out and the aluminum remain in solution on cooling.

PARAFFIN WAX.—With reference to the possibilities of using paraffin wax in conjunction with stearic acid as a softener of cotton goods after the goods have been bleached by the lime process, it has been found that paraffin wax and stearin will have no injurious effect. Both are frequently mixed with starch, to produce an excellent gloss and a brilliant white.

When used in combination with size compositions, paraffin wax and stearic acid will act not only as softeners, but also as lubricants. They will prevent the goods from sticking to the cans, as the cloth passes over the dryers, or through the calenders.

SECTION 10ss

TINPLATE MILLS

MANUFACTURE OF TINPLATE.—The manufacture of tinplate consists of the following operations in their order: Shearing of the tinplate bars, called pairs, which are the raw material for the process; heating the bars; matching; doubling and shearing; reheating the sheets; finishing the pack; opening the pack; black pickling; annealing; cold rolling; then white pickling, tinning, branning, assorting, and packing. The bars are either 7 or 8 inches wide and of varying thickness (the thickness of the bar being determined by the thickness of the gauge of the finished plate). They come from the steel works in about 30-foot lengths.

SHEARING.—There are many types of shears found in these plants, but the alligator type is the commonest. A petroleum pitch pinion grease is used as a gear lubricant, and black oil for the other lubrication. Some shops are equipped with a vertical shear, with an automatic stop-gauge, live roller approach tables, and pinch stop. The same lubricants are used.

HEATING THE BARS.—Sheet and pair furnaces are used to heat the bars and to reheat the sheets. In old-style plants, the furnaces for the sheets and bars are side by side, but in the more modern plants a tandem combination sheet and pair furnace is used. This consists of two furnaces, one behind the other, with a single combustion chamber.

MILL TRAIN.—In a modern mill, the rolls are 28 to 30 inches in diameter and 36 to 42 inches long on the barrels, arranged two high. The bottom rolls only are driven, the top rolls running by friction. The spindles are very long, averaging about 18 to 20 feet. The rolls may be driven by steam engines, connected by gears to the leading spindles, or they may be connected by rope drives. Electric motors, driving through helical-cut gear reductions, are sometimes used. The mill train turns at about 30 R. P. M.

ROUGHING THE BARS.—The heated bars are passed one at a time through the rolls, then passed back over the roll to the "roller," who again passes them through the rolls, while a "screw boy," who stands beside the roll housing, turns down the screws. The bars are given five or six passes singly, then the roller passes through a double pair, one on top of the other, continuing until the heat in the metal is exhausted. They are then taken to the doubling shears, which consists of a lever shear and a lever doubler. After the "pack" is doubled, squeezed, and sheared, it is ready for heating. After removing from the heater, the reheated pack is passed through the rolls again, the operation being repeated several times, each time with the screws set down a little harder.

SQUARING THE PACK.—This is done on the squaring shears, and gives the pack square sides, and slits it into two or more parts, as desired.

FORM 1 HP

SECTION No.____

RECOMMENDATION AND PRICE SHEET

NO.	BRAND	PRICE		
		LIST	CONTRACT	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

BASE BOX.—In the United States, the tinplate trade is based on what is known as a "base box." This consists of 100 plates, 14 x 20 inches, weighing 1 pound each. In Great Britain, it consists of 112 sheets, 14 x 20 inches, weighing 1 pound each.

OPENING OF PACK.—The pack is next opened; that is, the sheets are separated one from the other.

BLACK PICKLING.—The plates are pickled to remove the dirt, scale, and mill grease. The plates are placed on edge in a cradle and plunged up and down in an acid solution. Either a Mesta machine or a Gray machine is used for this purpose.

ANNEALING.—The plates are next packed onto a cast-iron annealing stand and brought to about 1500° Fahr. in the annealing furnace, then slowly cooled to about 400° Fahr. away from the air.

COLD ROLLING.—The finish is put on the plates in the cold rolling. This closes the pores left by the annealing process, and is necessary to prevent the plates taking up an excessive amount of tin. The cold-roll trains are about the same as the hot rolls, except that they are lighter. For 24-inch rolls, speeds are about: 42 R. P. M. for roughing, 44 R. P. M. for intermediate, and 46 R. P. M. for finishing. Electric motors are used in modern plants for driving these mills.

WHITE PICKLE.—This is done similarly to black pickling, but with a weaker acid solution.

TINNING.—In old-fashioned plants tinning was done by hand. The sheet being first dipped into a pot of molten tin, then into a pot of hot palm oil; then thrown into a pot of bran. Then it was polished by hand, with sheep-skin rubbers.

The process was improved and two pots were used, one containing tin and one containing palm oil. The sheet passes through the tin pot, which has one pair of rolls, and thence by curved guides to the oil pot, which has three pairs of rolls.

SECTION 10tt

TRACTORS

TRACTOR LUBRICATION.—The tractor consists essentially of a motor and a means of delivering the power developed by the motor to the tractor wheels and draw bar, or pulley.

Tractor motors may have one, two, four, six, or eight cylinders, and may be either of the horizontal or vertical type. The majority, or about 70 per cent., of the tractors in use in the United States have vertical types of motors. Both splash-feed and forced-feed lubricating systems are in use.

About 65 per cent. of the tractors in use in the United States in 1917 were equipped to burn kerosene, and in most cases started on gasoline. This feature is important in connection with their lubrication, because kerosene, having a higher boiling point than gasoline, is more difficult to vaporize, and has a greater tendency to liquefy in the cylinders. This condensation of the kerosene tends to wash the lubricating oil from the walls of the cylinders, and to also leak past the piston rings, and finds its way into the crank-case, where it affects the lubricating value of the oil carried there. This tendency of kerosene to find its way into the crank-case may be evidenced by the fact, that many times when testing lubricating oils in engines using this fuel, it will be found that the amount of oil in the crank-case has increased, rather than decreased, this increase being due, of course, to the contamination of the oil with kerosene.

On tractors equipped with mechanical lubricators, the operator should always turn the handle of the lubricator 40 or 50 times before starting up the engine, so that the bearings will be well supplied with lubricant before starting the engine.

A large percentage of the work done by the tractor is during the spring and fall months, and the lubricant used should have a low enough pour-point to insure it forming an efficient seal between the piston rings and the cylinder walls, as an imperfect seal will result in poor lubrication and will directly affect the compression and increase the fuel losses. This is particularly true when kerosene is used for starting. During the summer months the tractor operates under high heats from the sun, and when used for threshing the fact that the machine has no lateral motion, there is no aid given by the breeze that would have been set up when he machine is in motion, and the cooling capacity of the radiator is educed. The high temperatures will tend to improve the combustion n the motor, however and reduce the leakage.

A typical engine used for tractor work had the following general specifications: Four cycle, four cylinder, 800 R. P. M.; equipped with throttle and governor—centrifugal-type governor—forced-feed lubrication, with nine pounds oil pressure to all bearings, etc.

If the oil used for engine lubrication does not have the correct vis-

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RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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cosity, there will be a material increase in kerosene consumption per B. H. P. H. This may be as high as 25 per cent., due to leakage and imperfect combustion.

For tractors equipped with caterpillar, or track-layer, equipment, of which there are many models, and also the "tanks," the following method of lubrication is recommended: Thoroughly clean the tracks and driving mechanisms from mud and dirt, and apply a heavy-bodied, adhesive lubricant to the inside of the track, links, rollers, sprockets, chains, etc. This can be done with a brush, and the lubricant should be fluid enough to permit this form of lubrication. The lubricant must protect the mechanism from the cutting action of the road grit, etc. The lubricant used must not have a tendency to be washed off by water. A medium-bodied pinion grease (see index) will give good results.

The transmission, or speed-changing device, consists of spur gears and gear-shaft bearings. Transmission bearings may be of the roller, babbitted, ball, or bronze types. Sleeve type, babbitted, and bronze bearings require a thinner lubricant than do roller or ball bearings. Usually the transmission is enclosed in an oil-tight casing, and a light pinion grease, or a steam cylinder stock, will give good results, this being a compromise between the heavy lubricant demanded by the gears and the lighter lubricant demanded by the bearings. For transmissions which are not enclosed, use a heavy pinion grease for the gears that will not throw, and lubricate the bearings with cup grease from compression cups.

For the drive, which may be an internal gear, spur, gear, roller pinion, chain, or friction gears, the spur gear being the most general, and the chain drive being second, a heavy-bodied pinion grease should be used. The grease may be melted, and the chains removed from the machine and dipped into the boiling lubricant and then hung up to dry, thus insuring that the lubricant will work into all of the parts.

For wheel hubs and other bearings which may be equipped with grease cups, use a No. 3 or No. 4 cup grease.

SECTION 10uu

TRANSFORMERS

TRANSFORMERS.—For a brief description of the working principles of the electrical transformer, refer to the section on Electrical Engineering.

TRANSFORMER OILS.—Transformer cases are provided with oil, surrounding the coils, because oil is a better conductor of heat than air, and the heat caused by the electrical energy lost in the transformer is, therefore, more quickly transferred to the casing, and there dissipated to the air.

Transformer oil also aids in keeping the insulation soft and reduces the oxidation effect of the air.

Transformers are made with capacities as high as 14,000 kilovolt-ampères, and may contain as much as 11,000 gallons of oil.

It is believed that the maximum dielectric strength possible, to theoretically obtain, is about 70,000 volts.

SPECIFICATIONS FOR TRANSFORMER OILS.—The requirements of a satisfactory transformer oil are as follows:

(*a*) It must show an absence of moisture.

(*b*) It must show a good dielectric strength.

(*c*) It must have a low viscosity, to facilitate the heat transfer from the core and winding, to the case.

(*d*) The oil must have a flash-point of two or three times the "temperature limit" of the transformer.

(*e*) The oil must be neutral in its reactions.

(*f*) There must be an absence of any adulteration, or of animal and vegetable oils.

(*g*) The oil must not contain any metallic salts.

A typical specification for a transformer oil would read as follows:

(*a*) The oil must be a pure mineral oil, obtained by fractional distillation from petroleum, unmixed with any other substance and without any chemical treatment.

(*b*) The flash-point should not be less than 310° Fahr., and the fire-point must exceed 340° Fahr.

(*c*) The oil shall contain no moisture, acid, alkali, or sulphur.

(*d*) There shall not be more than 2 per cent. evaporation loss, when the oil is heated to 190° Fahr. for a period of eight hours.

(*e*) When heated to a temperature of 450° Fahr. and held at that temperature for five minutes, there should be only a very slight darkening of the oil, and when heated to this temperature for 30 minutes, there should be no dark particles or flocculent precipitate liberated.

(*f*) It is desirable that the color be No. 2 standard or better.

DIELECTRIC STRENGTH

INSULATING PROPERTIES.—The dielectric strength of clean, dry oil is usually not less than 40,000 volts, when tested between 1/2-inch brass spheres, set 0.15 inch apart, or about 22,000 volts when tested between one-inch discs, set 0.10 inch apart.

Care must be taken to prevent foreign matter from entering the transformer with the oil. Especial attention must be paid to this factor for transformers that are in the vicinity of cement mills and similar plants. Iron scale, from the iron drums, in which the oil is shipped, may be the cause of reducing the dielectric strength of the oil.

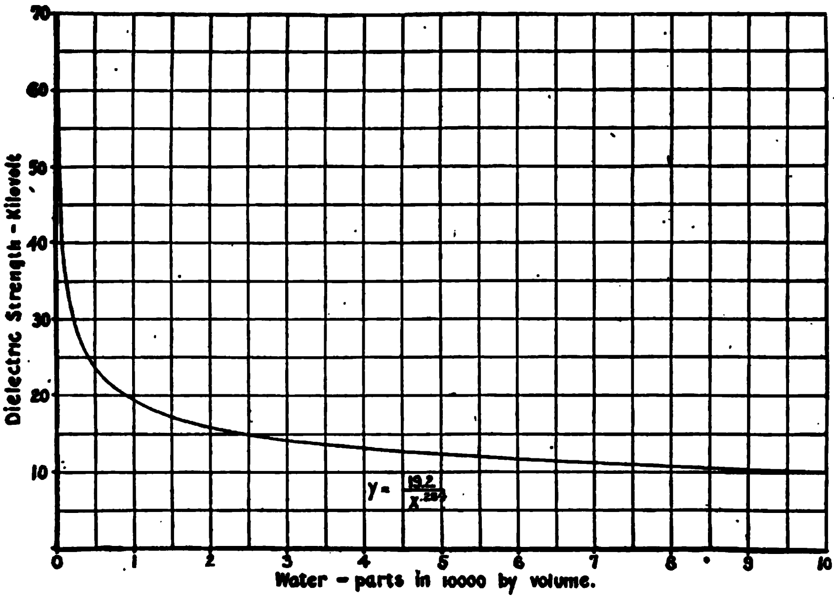

FIG. 1. SEC. 10*xx*.—Water-parts in 10,000 by volume.*

The presence of alkali, or acid, in transformer oil reduces the dielectric strength and has a destructive and corrosive action upon the transformer. The oil must contain no free sulphur, as this will attack copper. The oil should be neutral.

Digby and Mellis (*Journal Institute of E. E.*, 45) state: The presence of any soluble impurity in oil must tend to decrease its value as a medium offering resistance to the flow of an electric current. * * * The grading of oils according to specific resistance gives a fair indication of their purity. There is, however, a large range in the specific resistance, depending upon the presence or absence of impurities, in an amount determined qualitatively as "traces," rather than quantitatively as analytical ascertainable volumes.

Herschel (Bureau of Standards Paper No. 86, p. 32) states: With

* Curve obtained by the General Electric Co.

reference to transformer oils, the required degree of purity cannot be determined by chemical tests. The more sensitive tests for specific resistance, or dielectric strength, would be suitable for transformer oils. * * * The determination of purity is more easily accomplished by means of an emulsifier.

Mr. W. E. Temple, a consulting electrical engineer with wide experience in the testing of transformers, has made the following recommendations to the author, concerning the effect of moisture and other conditions upon transformer oils:

The decrease of dielectric strength of a transformer oil is very rapid with the increase of moisture content in the oil, particularly when passing from a "dry oil" to a moisture content of approximately one part in ten thousand (1–10,000). A sample under careful test showed a reduction of about 60 per cent. in puncture point when tested, first, in as near a "dry" condition as possible to obtain, and, secondly, with a moisture content of approximately 0.010 per cent. The same sample showed a puncture point of only 20 per cent. lower (in terms of its dry value) upon a moisture increase to 0.10 per cent.

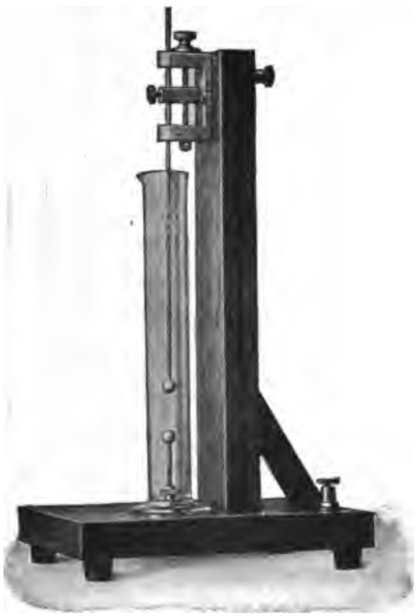

FIG. 2. SEC. 10uu.—Westinghouse oil testing set for transformer oils.

For indoor conditions, Mr. Temple advises that he would design the oil-containing apparatus on the "dry" basis, but for outdoor work he would assume that a certain amount of moisture was present: the exact amount to be assumed, to depend upon the conditions under which the transformer was expected to be operated.

Laboratory tests for oils to be used for electrical purposes must copy exactly the electrical and working conditions under which the oil is expected to work, in order that the tests may have any real value.

The effect of moisture upon the dielectric strength of transformer oil is illustrated by a curve shown in Fig. 1, Sec. 10uu.

TESTING DIELECTRIC STRENGTH OF OIL.—The oil-testing cup shown in Fig. 2, Sec. 10uu, is manufactured by the Westinghouse Electric and Manufacturing Company for making dielectric tests on oils that are to be used for insulating purposes. It consists of a graduated glass jar containing two testing terminals, each a brass sphere 1/2 inch in diameter. The upper sphere is adjustable in its distance from the lower sphere by hand or by a micrometer screw with a milled thread. The

general method for determining the dielectric strength is to immerse the spark gap in the oil, set at a known distance—generally 0.15 inch—and gradually raise the potential until rupture occurs.

In making the test, a suitable quantity of the oil is poured into the testing cup and the gap adjusted. The oil is allowed to stand for 10 minutes, to allow the air to escape. The testing voltage is then applied, low at the start and gradually raised, without opening the circuit, until the breakdown occurs. The oil is then agitated, and the test repeated until 10 breakdowns have occurred, the average of these being taken as the breakdown point of the oil.

The testing voltage should always be applied in the same manner. The gap may be fixed and an increasing voltage applied, or a constant voltage may be used and the gap gradually shortened until rupture occurs.

Another form of transformer oil-testing set is shown in Fig. 3, Sec. 10uu. This set is manufactured by the General Electric Company. The set consists of a testing transformer, with an induction regulator for voltage control and an oil spark gap. The transformer has a rating of 3 k. v. -a, at 30,000 volts, but may be operated at 10 per cent. over load. The set is built for both 25 and 60 cycles. The high-voltage winding is equipped with a voltmeter coil, for indicating directly the test voltage. The induction regulator allows a variation of voltage from zero to the maximum. A dial is attached to the top of the rotor shaft, and is graduated to give values of test voltage directly in kilovolts.

FIG. 3. SEC. 10uu.—General Electric transformer oil testing set.

The oil is tested between flat metal disks, located inside of the container, one electrode being stationary and the other having a micrometer-screw adjustment. About three quarts of oil are estimated to be required to make a test.

Fig. 4, Sec. 10uu, shows the oil receptacle and spark gap of the General Electric set. The discs are one inch in diameter and are normally set 0.1 inch apart. The receptacle holds about 150 cubic centimeters of oil.

TEST NOTES.—For oil in service, except in electrolytic arresters, the tests should show at least 30,000 volts for 1/2-inch brass spheres, set 0.15 inch apart, or 16,500 volts for 1/2-inch discs, set 0.10 inch apart.

For obtaining samples, use a standard, large-mouthed jar, that is easy to clean and to dry, and strong enough to ship. Cover corks with paraffin, to seal them against moisture. Take the sample from the bottom of the apparatus container, as the greatest water content will be found

there. Samples from barrels should be taken from about one inch from the bottom of the barrel by means of a glass tube. In some cases transformers will be found that have a plug sealed with white lead, instead of being provided with a test valve; and in this case care must be taken that none of the lead enters the sample, as a false test will result. The

FIG. 4. SEC. 10KK.—Oil receptacle and spark gap, General Electric oil testing set.

sample should be about one quart in size, except in small installation, where an eight-ounce sample is sufficient. When drawing the oil from a casing provided with a draw-off valve, allow enough of the oil to run out before taking the sample, to insure that the oil is really coming from the bottom, and is not the oil that was in the draw-off pipe.

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FORM 1 HB

SPECIFICATIONS

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PHYSICAL CHARACTERISTICS.—Viscosity of the oil is important; the more sluggish the oil, the slower will be the circulation and the transfer of heat. Heavy oil will not circulate through the ducts of the windings, and as a result a high temperature gradient exists between the oil and the windings.

For use in circuit breakers and electrolytic arresters, the cooling properties of the oil are not important, but its ability to form a good film is important. In the case of an arrester, the oil used must be capable of withstanding a quick blow from a plunger without excessive splashing. It is permissible with this apparatus to use a heavier oil than would be the case with a transformer.

Light-colored oils are in a way preferable, in that it is possible to examine the transformer connections when these oils are in the container without removing them.

The oils used must show no deposit or any change, except possibly a darkening in color, when in a transformer that is operated under average temperature conditions. If the oil forms a deposit, it will not only make the oil more sluggish and impair its cooling action, but this deposit will cling to the windings and fill the coil ducts and further impair the cooling effect.

The flash-over of an arrester, or the breaking of a circuit, or the failure of a transformer, produces high temperatures, and the flash-point of the oil must be sufficient to prevent its ignition under these abnormal conditions.

An important factor is the evaporation of insulating oils. While all insulating oils will evaporate slowly under operating conditions, it has been found that with some types of oils, this condition is increased. The oils used should have the lowest possible evaporation.

SLUDGING.—One of the main troubles met with in transformer oils is "sludging." This is a formation of pale to dark yellow deposits, and in some cases hard, black masses, which thicken the oil and collect at the bottom of the tank.

Michie (*Journal Institute of Electrical Engineers,* 51, pp. 215, 218, 219, 1913) states: Analysis of transformer deposits show that these contain a considerable proportion of oxygen, and as the original oils are free from oxygen, the only conclusion that can be drawn is, that the formation of these deposits is brought about by the oxidizing influence of the air on the transformer oil. The quantity of sludge which separates out in the oxidation process is largely dependent upon the degree of refinement of the oil.

TRANSFORMER OIL SPECIFICATION.—(Bureau of Aircraft Production, U. S. Army): The following general specifications, dated July 22, 1918, cover the requirements of the Bureau of Aircraft Production for an oil to be used in oil switches, oil circuit breakers, and for transformers up to 6600 volts:

(*a*) The oil is to be a straight-run, highly refined and highly filtered mineral oil, suited in every way for the uses above noted.

(*b*) The oil must be a petroleum product only, free from vegetable or animal oils, or fats of any kind, and must have an insulating value of not

less than 30,000 volts when measured with a spark gap, consisting of two 1/2-inch discs, faces vertical, spaced 0.2 inch apart.

(*c*) The viscosity of the oil, when tested in a Saybolt Universal Viscosimeter, at 100° Fahr., must not be above 105 seconds.

(*d*) The flash-point of the oil must not be less than 300 ° Fahr., when tested in the Cleveland Open Cup.

(*e*) One ounce of the oil must not congeal in a standard-four-ounce sample bottle at temperatures above 20° Fahr.

(*f*) The oil must not show an acid reaction of more than 0.03 per cent. calculated as SO_3, and must not gum or corrode metals under any condition.

DEMULSIBILITY.—Herschel (Bureau of Standards Paper No. 86) states: Transformer oils, as a rule, have a demulsibility of 1200, and since only very pure oils are suitable for this use, an additional proof is given that high demulsibility is an indication of great purity. (See index for Demulsibility.)

USE OF TANSFORMER AND INSULATING OILS.—For filling, use a metal hose in preference to a rubber hose, as the oil will dissolve the sulphur contained in the rubber, and this sulphur may attack the copper. Before putting the oil into the apparatus, it should be strained through several thicknesses of muslin, which has been previously washed to remove the sizing.

The best results will be obtained if the oil is put into the apparatus in dry weather, to prevent the entrance of moisture. The cover of the apparatus must be immediately replaced and allowed to stand long enough to permit the oil to enter the various crevices, after which the cover is removed and more oil is added to bring the oil to the oil-level mark, and then the cover is screwed on tight.

STORAGE AND SHIPMENT.—Insulating oil is usually shipped in drums with screw bungs, or it may be shipped in the apparatus in which it is to be used. It may also be shipped in lagged tank cars, the lagging being intended to prevent rapid changes in temperature.

Insulating oil in cans, or barrels, should not be stored in the weather. Drums should be stored on their sides, with the bungs down.

A drum of cold oil will sweat when taken into a warm room, and unless care is taken, this moisture will find its way into the oil. Before opening the seal on the drum, allow the drum to stand in the room until the oil has reached the room temperature.

INSPECTION OF OIL.—The apparatus containing the oil should be regularly inspected.

In transformers and oil circuit breakers, samples of the oil should be taken from the bottom, and if the samples show excessive discoloration, or deposits, the oil must be removed.

When filtering oil from a transformer tank, it is preferable to filter from one tank to another, so that the oil may receive more complete treatment than if drawn from the bottom of the tank and returned to the top of the same tank.

If much water is present in the oil, allow at least 24 to 48 hours for settling, before filtering.

Oil which has been damaged by overheating from a continuous over-

load may be treated and benefited in one of the driers and filters now on the market. The oil will, however, remain darker in color.

In large stations, which have a large amount of piping for the purpose of transferring the oils to and from the transformers, it will be worth while to frequently inspect the piping to ascertain that there is no moisture in the pipes.

Dust has a very bad effect upon the dielectric strength of oil, having about the same reducing effect as water.

The inside surfaces of transformer casings must be kept free from slime and other coatings, to facilitate the transfer of heat from the oil to the casing.

Large transformers are sometimes equipped with a circuiting system for cooling the oil, either with air or water. There is considerable risk attached to cooling with water, due to the possibility of the oil absorbing moisture. (For description of oil coolers see appendix.)

High temperatures in transformers, which will result from poor cooling, will cause the insulation of the windings to deteriorate.

When it is found that the deposits on the sides have gotten as thick as 1/8 inch, remove the oil and filter it, and clean ducts by forcing clean oil through all ducts.

The transformer must be regularly examined to note any reduction in the oil level due to evaporation.

Samples of the oil taken from the apparatus must be regularly tested for dielectric strength, and when the need of filtering is evident, this important operation should not be delayed.

Fig. 5. Sec. 10uu.—Transformer oil dryer and filter.

In electrolytic arresters, the oil will always contain some moisture, due to contact with the electrolyte. With this apparatus this is not a serious objection.

"Breathing," which will occur in even closely enclosed apparatus, due to temperature changes, will cause the oil to absorb some moisture.

For power-house and substation apparatus, inspection should be made once every three months. For outdoor transformers at least once a year.

It has been stated by several engineers, that traces of water in transformer oils may be removed by the following method: One pound of sodium is added to each 25 gallons of oil. Due to the high affinity of sodium for water, it acts very energetically with the evolution of hydrogen.

It was stated that the Niagara Company, by the above method, has obtained 20,000 volts with an oil which formerly had been reduced to only 3000 volts. The above method is merely included as being of interest, but no recommendation is made concerning its use.

TRANSFORMER OIL DRYERS.—The General Electric Co. manu-

facture a transformer oil dryer, as is shown in Fig. 5, Sec. 10uu. The elements comprising the dryer and filter are: Filter press, pump, motor, strainer, blotting paper, drying oven. The press, pump, and strainer are permanently piped together, and have a pressure gauge also connected. There are five sheets of blotting paper, 0.025-inch thick, placed between each filter plate and the adjacent frame, and the whole is held tightly together, which comprises the filter press. The oil is admitted at any pressure not over 100 pounds per square inch. The pressure is at first low, becoming higher as the paper clogs with dirt. After 30 to 60 minutes' operation, the filter is shut down and the papers are changed. After removal from the press, the paper may be dried in the electric oven, which is a part of the set. Here the moisture, which the paper has absorbed from the oil, is driven off and the paper is put into shape for reuse.

EVAPORATION OF TRANSFORMER OILS.—(C. E. Waters, Tech. Paper No. 13, Bur. Stds.): "The results obtained with two transformer oils lead to the conclusion that the factor of prime importance (with regards to evaporation) is, for a given temperature, the area of oil surface exposed to the atmosphere. Even when quite different weights of oil are heated in vessels of the same size, the actual losses are nearly equal. * * *"

FIRES

FIRES IN TRANSFORMERS AND OIL SWITCHES.—An arc, long sustained at the bottom of the tank, may heat the oil and cause it to burst into flames at the surface. In general, the danger of fire in an oil-insulated transformer is at the top of the tank and not at the bottom.

In large transformers, allowance is made for the increased pressures, due to arcs and fires, which would otherwise cause damage to the container. In large transformers, provision is made for the escape of the gases, so that high pressures cannot occur. Sometimes safety valves are attached, but it is found that when an explosion occurs in the oil container, the gas on rushing out of the case carries with it a part of the oil, in the form of spray. The best practice seems to be to make the case very strong, so that it will resist any explosion pressure.

Usually, in case of fire, the oil is permitted to run out of the case into an oil pit. It is better practice, according to several authorities, to permit the internal pressure of the explosion and fire, which, of course, acts outward, to prevent the inflow of air. In this manner, the oxygen which is contained in the case over the oil level is consumed, and there being no replacement, nothing is available for the sustaining of combustion, and, therefore, the fire will die out. Thus only oil will be burnt, and, as a result, the coils will not be damaged.

When the evidence of fire occurs, the best plan is to let the unit alone after the electric energy is shut off, but especial care must be taken not to permit the cover to be removed too soon after the fire has apparently become dead, because there would probably be an explosion, and, at any rate, the fire would restart.

One point to notice particularly is that the terminal boards in the transformer should be well covered with oil, so that arcing will not occur.

SECTION 10vv

STEAM TURBINES AND THEIR LUBRICATION

HORIZONTAL TURBINES

WESTINGHOUSE STEAM TURBINES.—The lubrication of this type of turbine is accomplished by a closed oiling system, through which the oil is circulated by means of a pump, which is usually gear-driven from the main shaft. In the older types of machines the pump was of the plunger type, and in the newer machines a rotary pump is used.

The bearings are flooded at low pressure. In the usual average-sized machine, the oil is drained from the bearings and passed through a strainer into a settling tank. The oil is next passed through a cooler, which is of the counterbalanced type; that is, the oil enters at the opposite end from the cooling water, the water being passed through a number of coils and the oil flowing about them. Usually the oil reservoir, cooler, and piping are located below and about the machine, being covered by a corrugated steel floor plate to improve the neatness of installation.

For those turbines in which the oil-relay governing system is supplied with oil from the lubricating system, a higher pressure is produced by the pumps. The oil for the circulating system is passed through a spring-loaded, pressure-reducing valve, and thence through the cooler. The small quantity of oil for operating the valve passes to a relay cylinder, and then exhausts into the cooler. (See section on Turbines.)

In turbines where the speeds are very high, the spindle tends to revolve on its gravity axis instead of on its mechanical axis. The method used to overcome this action in the Westinghouse turbine is worthy of notice and is described in another section of this book. (See index.)

For the ordinary-sized Westinghouse turbine, the following oil as generally specified below will satisfy all conditions:

(*a*) Viscosity: 145 to 150 at 100° Fahr. (P. B.), or 180–200 at 100° Fahr. (A. B.).*
(*b*) Flash: 390° to 400° Fahr.
(*c*) Neutral oil, or non-emulsifying oil.

CURTIS STEAM TURBINES.—The oil for this type of turbine is supplied by a general circulating system. In the usual machine, a pump, gear-driven from the main shaft, supplies the necessary oil pressure. In large machines, a separate steam-driven pump is provided. In certain cases, positive cooling is produced by water pipes imbedded in the bearing metal.

The same oil is recommended for these turbines as is described under the Westinghouse turbine heading.

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* NOTE. For the larger machines the viscosity should be increased to 180 to 190 at 100° Fahr (P. B.), or 275–300 at 100° Fahr. (A. B.).

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SPECIFICATIONS

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DE LAVAL STEAM TURBINES.—The lubrication of this type of turbine should be considered from the standpoint of a high-speed engine. The bearings are usually supplied with oil by a multiple-feed oiler, pipes being carried directly from the main sight-feed box to the different bearings.

A strictly non-emulsifying oil of 145 to 150 Vis. at 100° Fahr. (P. B.), or 180–200 at 100° Fahr (A. B.), will give satisfactory results in this turbine.

TERRY TURBINE.—The ball holder, which is the little thrust bearing mounted on the governor lever, in case it is provided with an oil cup, should be supplied with the same oil as provided for the main bearings. In case a grease cup is provided, a No. 2 cup grease should be used for the single-ball type, or a No. 1 for the ball-race type. In this latter case, if heavy grease, or an insufficient quantity is used, it may be thrown from the balls.

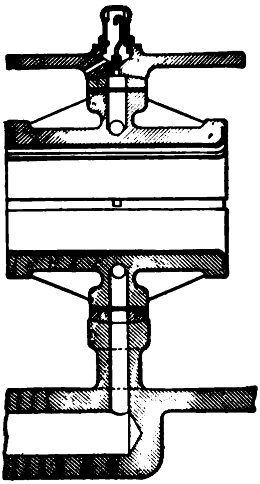

FIG. 1. SEC. 10vv.—Bearing of Allis-Chalmers turbine, side view.

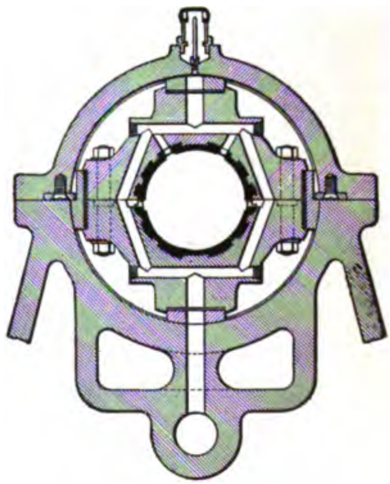

FIG. 2. SEC. 10vv.—Bearing of Allis-Chalmers turbine, showing oil passages, end view.

Terry turbines are ring oiling, using two rings Forced oiling, or water cooling, are supplied in addition in some cases where high surrounding temperatures are to be met.

For the bearings of the Terry turbine, without reduction gears, with either forced or ring feed, use an oil of 130–145 viscosity at 100° Fahr. (P. B.), or 180–200 (A. B.). For lubrication of installations where there are reduction gears and either forced or ring feed, use an oil of 245–280 viscosity at 100° Fahr (P. B.), or 300–350 (A. B.). In Cases where there is bad gear noise or vibration, use an oil of 480 viscosity at 100° Fahr. (P. B.), or 500–550 (A. B.).

STURTEVANT TURBINE.—See index for the "channel scroop ring" oiling device, such as is used on these turbines.

ALLIS-CHALMERS TURBINES.—Fig. 1, Sec. 10vv, and Fig. 2, Sec. 10vv, show the bearings of these turbines. They are of the self-

adjusting, ball-and-socket type. The lubrication of the four bearings, two for the generator and two for the turbine, is effected by supplying the oil to the middle of each bearing and allowing it to flow out of the ends. The oil-pipe connections are located in the lower half of the casing, the oil passing through the bottom bearing seat and around the bearing, as shown in Fig. 2, Sec. 10vv, and admitted to the journals on a horizontal centre line and on the top.

A sight oil vent is provided on each bearing. This oil vent is always open, and prevents accumulation of air in the oiling system, and also furnishes a means of determining at all times whether the bearings are receiving a sufficient amount of oil. It is not necessary to furnish these bearings with oil under pressure, but only under a head of a few feet, sufficient to cause the oil to run through the bearings.

NOTES.—The various mechanical features affecting the lubrication of the turbines referred to above are described in another section of this book. (See index.)

In some cases, a central oiling system is employed instead of individual oiling systems, particularly where there are two or more turbines installed. One of the greatest advantages of a central system is that it can be designed to contain large quantities of oil in the settling tanks, thus allowing the oil to have a reasonably long rest between the periods of passing through the bearings.

It is always good practice to provide two oil pumps for all turbine oiling systems, so that one pump can be held in reserve in case the other gets out of order. Due to the high-bearing speeds, the oil supply must be plentiful to prevent overheating.

FORM 1 HP

SECTION No.______

RECOMMENDATION AND PRICE SHEET

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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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VERTICAL TURBINES

Vertical turbines are provided with step-bearing pumps to force the oil between the contact surfaces of the step bearings, against the "squeezing-out" effect of the weight of the rotating element.

STEP-BEARING PUMPS.—Step-bearing pumps should always be provided in duplicate to prevent the possibility of lack of oil pressure

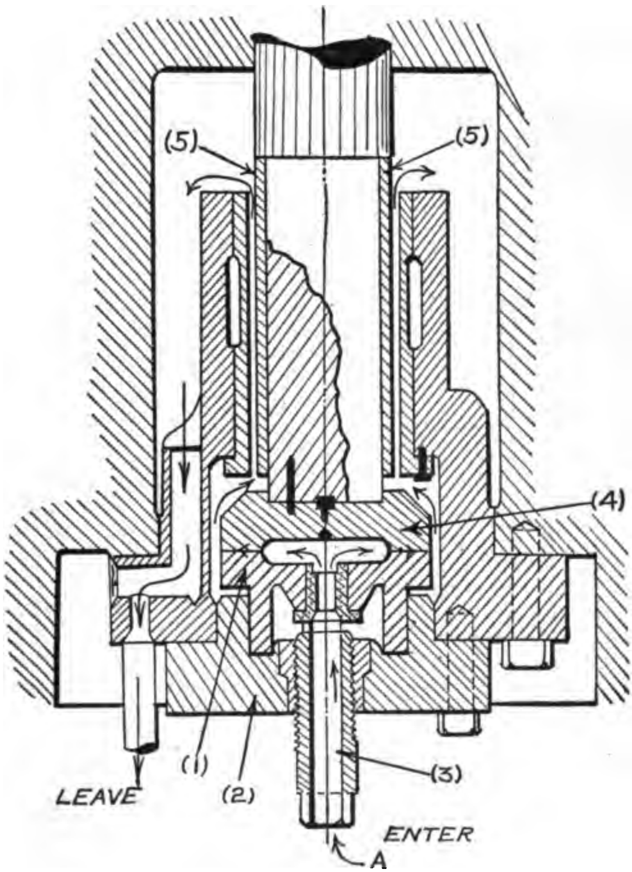

FIG. 3. SEC. 10ww.—Sectional view of a vertical turbine step bearing.

causing a shutdown. The pumps should always be equipped with a good governor.

When the plant contains several machines an accumulator should be provided. Auxiliaries, such as dry vacuum pumps, should be equipped with grease cups. A medium grade of grease, such as No. 3 standard, is recommended for use in these cups.

OIL FILTERS.—The filters should be located so that they are readily accessible and easily cleaned. Good lubrication is impossible without efficient filtering, and only a frequently cleaned filter will produce good results.

LUBRICATING SYSTEMS.—Fig. 3, Sec. 10vv, shows a typical, plain vertical turbine step bearing and the method of lubricating it.

The upper and middle bearings of vertical turbines are of the regu-

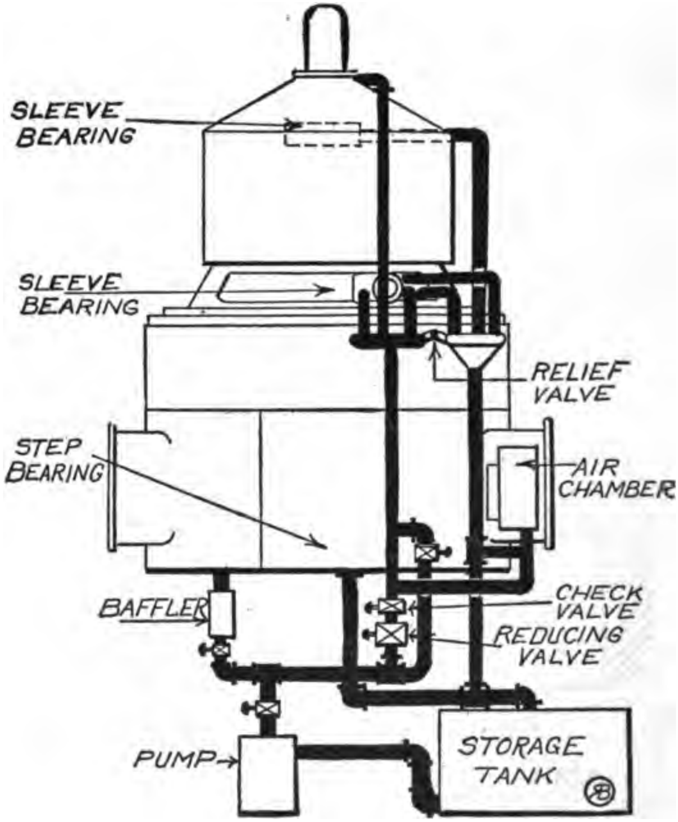

Fig. 4. Sec. 10ww.—Lubricating system for vertical steam turbine.

ar sleeve type. The lower bearing is a step bearing, and the weight of the revolving element is supported by this bearing. The contact surfaces of the step bearing must be operated by an oil film under pressure, and usually this pressure is about 600 pounds. The oil is forced between the upper and lower bearing blocks (4) and (1), through the pipe *A* (see Fig. 3, Sec. 10vv).

The oil, after escaping under the block, passes upward through the steadying bearing and is drained back into the oil tank.

The arrangements of the oiling systems used with these machines may be varied somewhat to meet individual conditions.

A typical lubricating system for this type of turbine is shown in Fig. 4, Sec. 10vv. A tank of sufficient size to contain all of the oil and to permit of a good-sized surplus is fitted with suitable straining devices and a heating and cooling coil. This tank is located at a level low enough to receive all of the oil by gravity, from all of the points of lubrication. A pump draws oil from the tank and delivers it at a pressure approximately 25 per cent. higher than is required to sustain the weight of the revolving element.

The vertical turbine is not being as generally used now as in the past, as most of the manufacturers are recommending horizontal turbines.

As is shown in Fig. 3, Sec. 10vv, the bearing plate (1) is made of cast iron and is held by the frame (2). It is carried by a large screw (3), which passes through a steel nut, coming into contact with a steel block set in the bearing plate as shown. The step plate is shown at (4), which is keyed to the lower end of the shaft. Both plates are recessed, so that the contact surface is collar shaped. The guide bearing is shown at (5). The oil enters at *A*, through the centre of the screw, and the path is shown by the arrows.

In operation, the contact surfaces of the steps should be separated by a film of lubricant.

TURBINE OILS

GENERAL.—Since the consumption of lubricating oil in a turbine is small, the loss of oil is practically due only to leakage, and a small amount of evaporation and wear, the price paid for the oil should be a secondary consideration, the prime consideration being its suitability for the purpose.

A satisfactory turbine oil must possess the following requirements:

(*a*) It must be absolutely non-emulsifying, and should be a filtered neutral oil. The best results are obtained with paraffin-base oils, but turbine oils that will give good service are made from asphalt-base crudes, provided they are carefully chosen. The asphalt-base oils must be particularly examined to ascertain their freedom from acid and their non-emulsifying qualities. (See Demulsibility Tests in index.)

(*b*) The viscosity of turbine oils should not be excessively high, even for the heaviest loads. The primary reason for this condition lies in the fact, that it is not advisable to start with an abnormally high viscosity oil in order to have the proper viscosity obtained at the working temperature, as this would be a particularly objectionable condition in a closed circuit system.

(*c*) There should be less than 1/4 of 1 per cent. free acid in the oil.

(*d*) Turbine oil must be a strictly pure mineral oil.

(*e*) The flash-point should be 390° Fahr. or over.

Steam turbines have an average bearing clearance of 0.006 to 0.010. The film pressure varies from 5 to 15 pounds per square inch.

Usually, in practice, the oil must circulate at periods of from 10 minutes to one hour.

Circulating pumps should never take their supply from the bottom of the settling tanks, because efficient settling will be interfered with.

As an illustration, a typical 35,000 K. W. turbine contains about 1000 gallons of oil. For this installation partial filtration of about 1000 gallons per hour would be required.

Designers have found that it is good practice to maintain the pressure of the oil, as it passes through the cooling pipes, at a higher pressure than that of the water which is circulated about these pipes for carrying off the heat. If a system is operated in this manner and a leak in the oil pipes occurs, the water will not enter the tubes and contaminate the oil.

It is very important to keep the lubricating system tanks and filters as free from moisture as possible. Constantly circulating the oil through the system tends to break it down and to destroy its non-emulsifying properties. The first indication that the oil has been broken down is usually a thick, slimy deposit in the strainers and filters. In time this deposit will become hardened.

DRAINING OF TANKS.—Tanks should be frequently and systematically drained, and all slime and foreign matter removed. Recent installations provide a reserve tank, so that the oil in one tank can be used while that in the other tank is settling, or draining.

EXPOSURE TO THE AIR.—In some plants, warm oil coming from the bearings is allowed to drop from the exit pipe outlet through the air for about a foot to a funnel, and then flow through the filters. This condition should never be permitted, because the warm oil will absorb dust very readily from the air, and there will be constant trouble from deposits.

STEEL BARRELS.—If it is convenient, turbine oil should be delivered in steel barrels, to avoid any possibility of glue from a badly glued barrel, or moisture from exposure of the barrel to the weather, getting into the system.

MARINE TURBINE INSTALLATION.—On a large battleship the maximum temperature of the turbine oil after passing through the bearings was 105° Fahr. under normal conditions. The maximum reduction in temperature by a well-known make of film cooler was 25° Fahr. The specific heat of a typical turbine oil was found to be 0.468 at 100° Fahr.

THERMOMETERS.—Thermometers are usually found at the outlets and inlets of turbine-oiling systems. They should be located as near to the bearings as possible and the temperatures frequently noted.

TEMPERATURE OF OIL.—The outlet temperatures of the oil leaving the bearings should reach a maximum very soon after starting the machine, and should continue at a fairly constant temperature thereafter.

WATER IN SYSTEM. — Water mixed with oil in a system is hard to detect and difficult to remove. The only way that it can be removed is by settling and draining the oil, allowing at least 48 hours for this operation.

THE BAFFLER.—The baffler is a device for restricting the flow of oil supplied by the pumps to the step and guide bearings of a vertical turbine.

This device consists of a square-threaded plug in a suitable casing. The oil under pressure from the pump enters one end of the casing, and, due to the circular path it must travel about the threads of the plug, the flow is steadied and does not fluctuate as much with any change in pressure or load on the step bearing as would otherwise occur.

A sectional view of a "baffler" is shown in Fig. 5, Sec. 10vv.

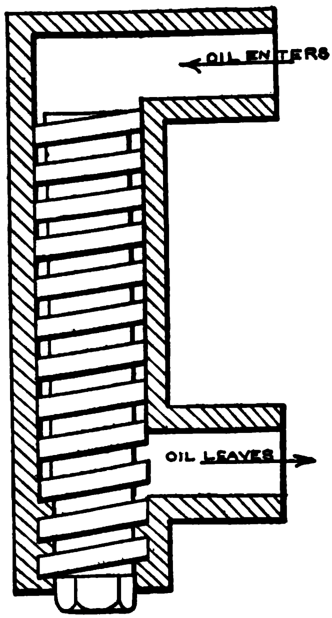

FIG. 5. SEC. 10vv.—Baffler.

It has been found that there is a definite rate of flow of the lubricating oil between the blocks of the step bearing, which will give the best efficiency for various speeds and loads. By means of the baffler or governor, the flow of oil can be definitely adjusted, and it is possible to maintain it practically constant.

The baffling effect may be lessened or increased by screwing the plug in or out of the casing, thus increasing or decreasing the length of the travel of the oil.

This device is also useful in cases where there are several machines having their oil supplies tapped into the same supply main, and equipped with a common pump. The baffler of each machine independently governs the flow to the step bearing of that machine, depending upon its own independent requirements and load.

COST OF LUBRICATION.—For a public service electric plant equipped with reciprocating engines and turbines, using a forced-feed, return lubricating system, the cost of lubrication will generally average between five (5) and ten (10) cents per kilowatt year.

CYLINDER OIL ON TURBINE BLADES.—In turbines of the low-pressure type, which take their steam from the exhaust of reciprocating units, it has been found that cylinder oil, which has been brought over with the exhaust steam, was deposited upon the blades of the turbines in appreciable quantities. This caused in some cases reduced efficiency.

In order to avoid the necessity of taking down the machine, in order to clean each blade, the following method has been used with success: Kerosene or other light petroleum oil, such as "torch" oil, was fed into the steam line, by means of a forced-feed lubricator, at the rate of one-half pint per hour.

Good results were obtained. The cylinder oil was completely removed, and in one case an increase in efficiency of three (3) per cent. was noted.

STEAM TURBINE OILS AND FATTY ACIDS.—Messrs. Wells and Southcombe, in the *Journal of Chemical Industry*, state: "The property most essential in oil for steam turbines; namely, non-emulsification, is one that largely governs successful lubrication. * * * The phenomenon of emulsification is dependent upon the colloidal properties of the oil, while deëmulsificiation is brought about by a greater concentration of hydrogen ions. Consequently one would expect that oil (fatty) containing the higher members of the fatty acid group to possess an emulsifying tendency, while one containing the lower members will possess a deëmulsifying tendency." In their U. S. patent they state: "A non-emulsifying oil is prepared by adding 0.8 per cent. of butyric, cinnamic or an oil soluble sulfonic acid to hydrocarbon oil. Certain naphthenic acids also exert this deëmulsifying effect." They also state that the water of condensation is the deciding factor, and that the kind of fatty acid treatment (germ) must be carefully adapted to the water as well as the oil.

SECTION 10ww

WASHING OIL (TOLUOL RECOVERY)

WASHING OIL.—In stripping toluol from illuminating gas, a scrubbing oil is used in the recovery. An oil which has been used for this purpose with success had the following general specifications:

1. 34 to 36 gravity Bé. at 60° F.
2. 65 to 70 viscosity Say. at 100° F.
3. Below 40° F. pour test.
4. When 500 c.c. of the oil are distilled with steam at atmospheric pressure, collecting 500 c.c. of condensed water, not over 12 c.c. of oil shall distil.
5. To limit the volume lost when washing with sulphuric acid, the oil shall not show a loss of more than 10 per cent. by volume in washing with sulphuric acid (100 per cent.) when two and a half times its volume of sulphuric acid is used. The oil is washed for five minutes and then settled for two hours.
6. A sample of the oil with flask distillation should not show any distillate below 240° Cent. temperature of the oil.
7. When equal volumes of the oil and pure distilled water are shaken together for ten minutes, there should be at least 90 per cent. separation after ten minutes standing.

Some specifications call for a viscosity not over 56 Saybolt at 100° F., the oil not to thicken or cloud at 25° Fahr., at least 95 per cent. to separate from water after agitation for 10 minutes, not more than 14 per cent. loss in volume when agitated with 100 per cent. sulphuric acid for 5 minutes and settled for 2 hours. Ordinary gas oil has been used by some operators. One investigator states that an oil high in olefines, unsaturated hydrocarbons, increases the amount of gumming in the used oil.

METHOD.—To recover light oils from gas, the usual method is to bring the gas into contact with a medium which has a solvent action upon the light oils. It is desirable to have the oil a little warmer than the gas to prevent condensation of water from the gas into the oil. The washing medium generally used is a petroleum distillate called "straw oil." To separate the light oils from the wash oil in which they are dissolved, some form of still is used. In small plants either intermittent or continuous stills may be used, and in large plants continuous stills, in which steam comes into contact with the wash oil and boils off the light oils, are used. Some plants use superheated steam. The apparatus in which the gas is brought into contact with the wash oil, is called a "scrubber" or benzol washer. It may be of the rotary type, bubble type, spray type, or tower type. Fig. 1, Sec. 10ww, shows a diagram of a typical plant for light oil recovery.

ABSORBING OR WASHING OIL

ABSORBING OR WASHING OIL FOR RECOVERY OF TOLUOL.—In the acquisition of toluol from the stripping of illuminating gas, an oil used with success had the following tests:

(*a*) Gravity at 60° Fahr. should be lighter than 34° Fahr. (In order to make the oil separate easily from water.)

(*b*) Viscosity Saybolt at 100° Fahr. should not be more than 70 seconds.

(*c*) Pour test not over 40° Fahr.

(*d*) When 500 c.c. of the oil are distilled with steam at atmospheric pressure, collecting 600 c.c. of the condensed water, not over 12 c.c. of the oil shall distil.

(*e*) The oil shall not lose more than 7 per cent. by volume in washing with 2 1/2 times its volume of sulphuric acid for 5 minutes and settled for 2 hours. This specification is required by some concerns, but may be eliminated, as it has no bearing upon the use of the oil.

(*f*) A sample of the oil in flask distillation shall not show any distillate below 260° Cent. temperature of the oil (not temperature of the vapor).

(*g*) When equal volumes of the oil are shaken together, there shall be at least 90 per cent. separation in ten (10) minutes. This specification can be made more rigid by substituting a demulsibility value. (See index for demulsibility testing.)

GUMMING.—One investigator found that an oil containing a high percentage of olefines, unsaturated hydrocarbons, increases the amount of gumming in the used oil.

* **ABSORPTION OIL.**—For gasoline absorption oil, a 300° mineral burning oil, preferably a re-run oil, is sometimes used.

Another oil that has been used for this purpose is a light pale neutral, having a gravity of about 34° B. and a viscosity Saybolt of 80 at 70° Fahr.

ABSORPTION OIL FOR BENZOL (STRAW OIL).—An oil that has been successfully used for benzol absorption has the following specifications:

Specific gravity, not higher than 0.875. Viscosity, not higher than 185 at 100° F. Say.

When 100 c.c. of the oil are shaken with 100 c.c. of water and allowed to stand 10 minutes, at least 95 per cent. of the oil should separate, without an emulsified layer of water and oil at the dividing point of the water and oil.

When treated with a two-to-one mixture of 93 per cent. sulphuric acid, 2 parts, and fuming sulphuric acid containing approximately 25 per cent. of free SO_3, the oil should not lose more than 10 per cent. in volume when treated with 2 1/2 times its volume of the described mixture, the above being a test for olefines or unsaturated hydrocarbons.

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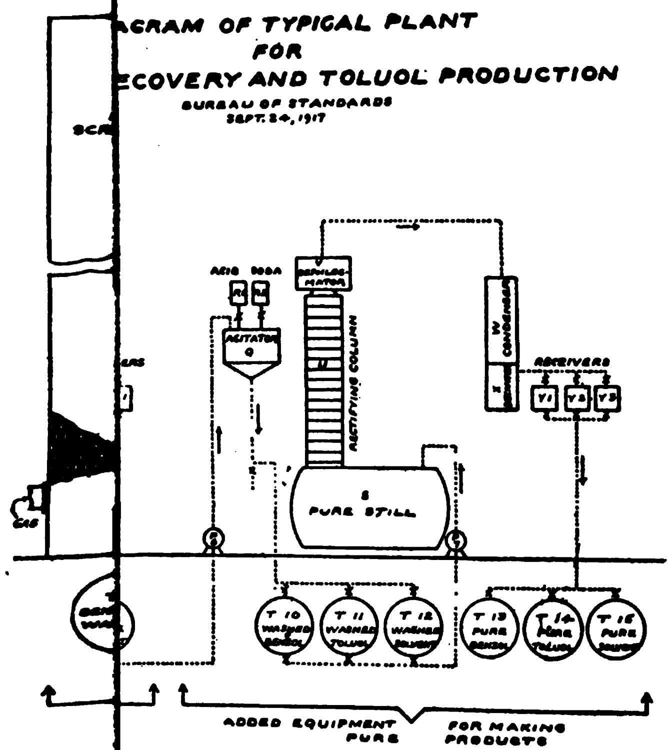
* NOTE. See index for comparison of asphalt- and paraffin-base oils for gasoline absorption. Paraffin-base oil is claimed to be a better absorbing vehicle.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FOR
ECOVERY AND TOLUOL PRODUCTION
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T 11 WASHED TOLUOL
T 12 WASHED SOLVENT
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FORM 1 HP

SECTION No.

RECOMMENDATION AND PRICE SHEET

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☞ NOTE A method for using these data sheets in the following sections is as follows: On the margin of the text, beside the description of a process, lubricating requirements of a machine, or other basis for making selection or recommendation, mark a number. On the data sheet opposite this number insert your brand name or oil, that meets these requirements, and the price, in the proper spaces. This will give a complete handbook and price book in one, and if filled out properly will be a guide to one not familiar with the industrial uses of oil products, which will insure an accurate recommendation and greatly assist him. Space on the back of the sheet provides for specifications.

(OVER)

FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY °Be	FLASH ° F.	FIRE ° F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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SECTION 10xx
WASTE MANUFACTURE

Cotton waste, which is used for many purposes, is made by shredding rags that are obtained from mills and other sources.

For certain grades of waste, such as colored waste, an oil known as "stock oil" is sprinkled over the rags, to prevent excessive dust and lint from rising during shredding and to weight the waste.

A typical "stock oil" would have the following general test:

Flash: 300° to 310° Fahr.
Gravity: About 30° Baumé.
Cold test: About 30° Fahr. (cloud).
Color: Pale yellow.
Viscosity: About 55 to 65 at 100° Fahr.

It is sometimes desirable to know the weight per gallon of stock oil, so that the amount of increase in the weight of the finished waste can be estimated, for various "mixes" of the oil. This weight can, of course, be determined if the gravity of the oil is known.

Often the purchasers of waste limit the amount of oil that will be permitted in its manufacture.

SECTION 10yy
WATER WHEELS

WATER-WHEEL GENERATORS

The utilization and development of water-power for the production of electrical energy has become very general throughout the United States.

There are two types of water-wheel generators, namely: Horizontal and vertical.

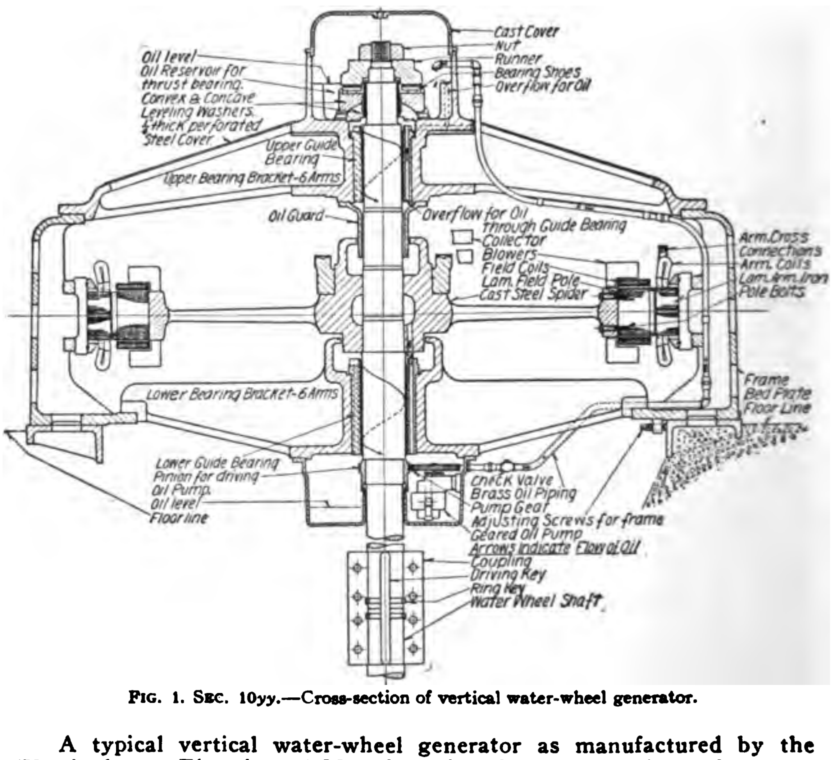

FIG. 1. SEC. 10yy.—Cross-section of vertical water-wheel generator.

A typical vertical water-wheel generator as manufactured by the Westinghouse Electric and Manufacturing Company is shown in cross-section in Fig. 1, Sec. 10yy.

The oiling system is plainly indicated, and the path of the oil travel is shown by arrows.

A good-bodied, filtered, neutral engine oil will give the best results in this type of machine. The oil must be *strictly neutral* and must possess

FORM 1 HP

SECTION No.

RECOMMENDATION AND PRICE SHEET

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FORM 1 HB

SPECIFICATIONS

NO.	BRAND	GRAVITY Be	FLASH °F.	FIRE °F.	SAYBOLT VIS: @ 100° F.	SAYBOLT VIS: @ 212° F.	COM-POUND %	COLOR	NOTES
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no emulsifying properties. It must be free from any adulteration. The viscosity of the oil should be 180 to 200 Vis. at 100° Fahr. (P. B.), or a non-emulsifying oil of 210–220 Vis. at 100° Fahr. (A. B.).

The pump for supplying the necessary circulation of oil is geared to the main shaft. A check valve is coupled in the feed line to keep it full and prevent the oil running back, which would require the pump to fill the line, before oil would be supplied to the upper bearing, when restarting the machine after it has been shut down.

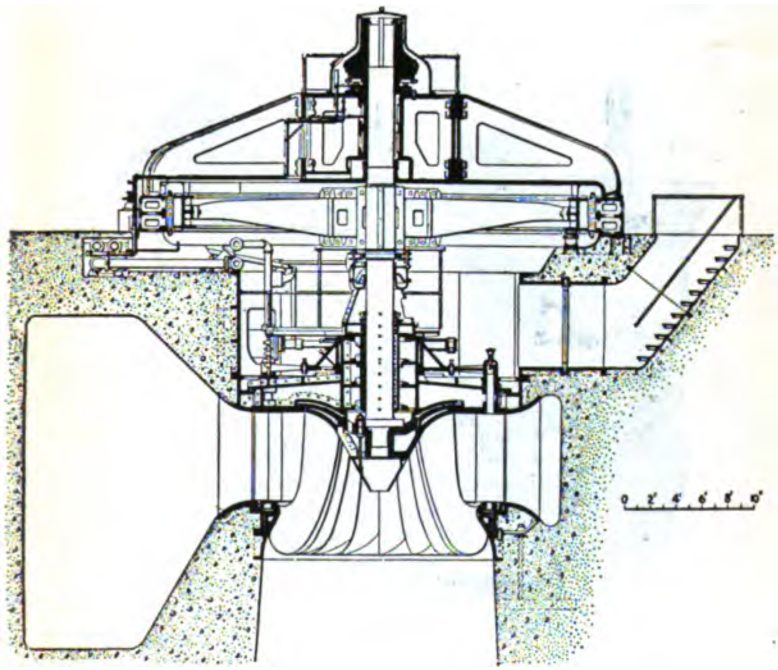

Fig. 2. Sec. 10yy.—Sectional elevation of one of the ten main units of the Cedar Rapids Manufacturing and Power Co.

VERTICAL WATER-WHEEL GENERATORS.—Kingsbury thrust bearings are used extensively to take up the thrust of hydro-electric units. Fig. 2, Sec. 10yy, shows a sectional elevation of a main unit of the Cedar Rapids Manufacturing and Power Co. The generator is about 37 feet in diameter. The Kingsbury thrust bearing is mounted just under the bell-shaped thrust block at the upper end of the shaft. The thrust load is 550,000 pounds. The main thrust bearings are 61 inches in diameter. Fig. 3, Sec. 10yy, shows a main thrust bearing, with the runner lifted off of the shoes. The bearing is surrounded by a bell-shaped housing, which contains 400 gallons of oil. The oil is circulated from a central system at the rate of 15 gallons per minute. It enters the bearing house at 25° C.

and leaves about 4° C. hotter than it enters when the unit is running at normal speed—55.6 R. P. M. Friction loss is about 10 H. P. At 10 R. P. M. on test, the temperature rise of the oil in the housing was about 1° C. when oil was supplied at 15 gallons per minute. With the oil supply cut off and the unit run for one-half hour, the mean temperature of the oil in the housing rose about 2° C. in this time. The oil used had a viscosity of 135 seconds at 100° F., Say. With this light oil, the units, when slowing down to stop, will run 5 R. P. M., or less, before the oil film breaks.

Fig. 4, Sec. 10yy, shows a vertical section of a vertical Kingsbury thrust bearing, such as used at the Chattanooga and Tennessee River

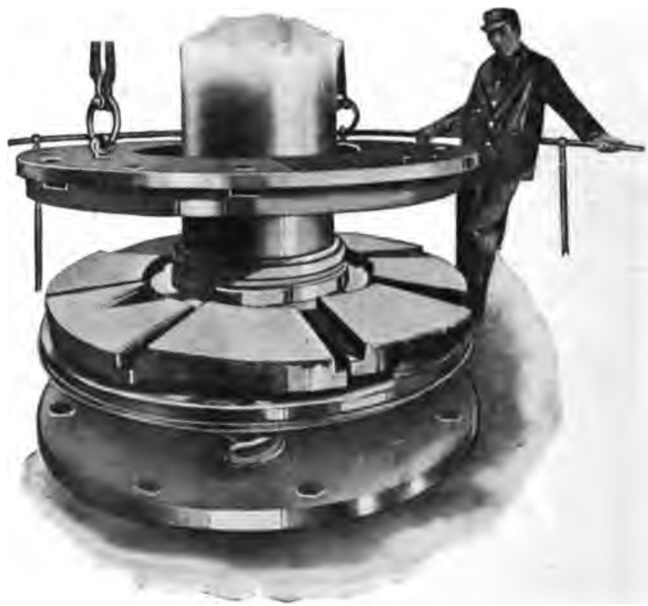

FIG. 3. SEC. 10yy.—Kingsbury main thrust bearing, with runner lifted off shoes.

Power Co. Each of these bearings carries 180,000 pounds thrust at 100 R. P. M. The thrust-bearing shoes rest on the supporting discs, which, in turn, rest on the adjusting screws. The cut shows the arrangement of the housing and oil pipes.

For the Cedar Rapids Manufacturing and Power Co. plant, above referred to, the used oil from the thrust and guide bearings is passed through one of three special Peterson power-plant filters, having a combined filtering capacity of 22,500 gallons per hour. Each filter is equipped with 70 18 x 36-inch filtering units, having a total of 630 square feet of filtering surface, and a filtering rate of 7500 gallons of oil per hour. Fig. 5, Sec. 10yy, shows the construction of these filters. The purified oil from the filtering compartment passes over the inclined cooling coils before

reaching the clean-oil department. Each filter is equipped with a vertical, submerged motor-driven centrifugal pump, automatically started and stopped by controllers operated from a float. The automatic control is arranged so that the filters are automatically cut in or out of service, to take care of the variation in demand for oil.

WEAR OF OIL.—An interesting result at the Great Falls Power Company was reported, where a continuous system was used on Kingsbury thrust bearings and the guide bearings, each thrust bearing carrying a load of 348,000 pounds at 200 R. P. M. There were six vertical G. E.

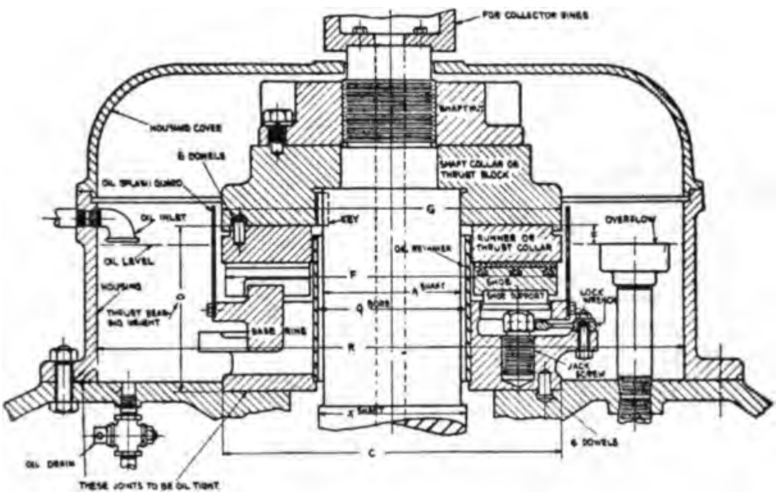

FIG. 4. SEC. 10*yy*.—Vertical section of vertical Kingsbury thrust bearing.

generators, with S. Morgan Smith turbines. Circulating 20 gallons of oil per minute per wheel, after three years' running, no new oil having been added to the make-up, the oil was sampled and tested, with the following results:

	New oil	Oil after three years
Bé. gr.	26	21.2
Flash	342	344
Vis. Say. at 100° Fahr.	142	167

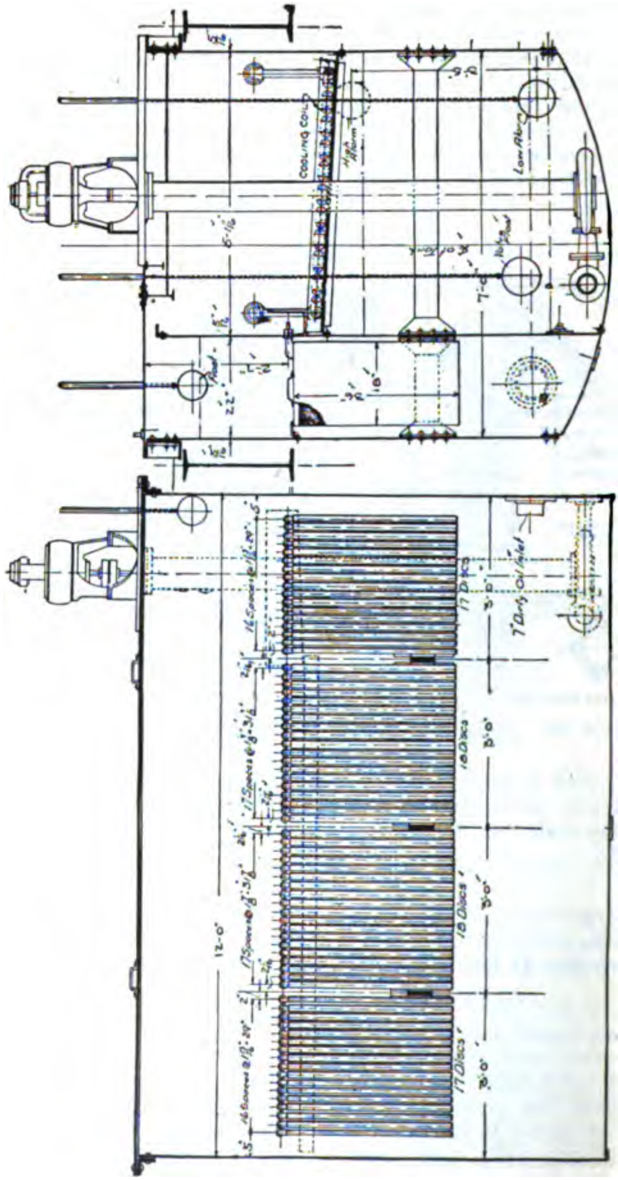

FIG. 5. SEC. 10yy.—Sectional view of Peterson Filter at Cedar Rapids Manufacturing and Power Co. Plant.

SECTION 11

INDUSTRIAL OIL SPECIFICATIONS

ADVANTAGES.—The advantages of buying petroleum and other oil products under specifications may be outlined as follows:

1. Bids may be obtained and compared from many oil companies on the same grade of oils, thus assuring by competitive bidding the lowest prices.

2. The claims and counter-claims of the various oil companies, as to the particular merits of their own brands of oils are eliminated.

3. The purchasing and application of the oils is standardized.

DISADVANTAGES.—The disadvantages of buying lubricating oils under specifications are outlined as follows:

1. There are very few chemists, outside of those specializing in the oil industry, who are equipped with sufficient knowledge of the characteristics of the various grades of lubricating oils and greases to enable them to prepare fair and intelligent specifications.

2. The crude oil conditions are constantly changing, and, therefore, a specification calling for a certain viscosity and gravity this year, may allow competitive bidding from many oil companies. Then, due to a falling off in the production of certain fields and the increased production in other fields, the specifications may quickly become obsolete and limit the number of competitors for the business in succeeding years.

The gravity and the other characteristics may call for an oil from a particular field in which the conditions have materially changed. The result is an increased price for the oil, or restricted bidding.

*3. In preparing specifications, some particular oil may be used as a sample. Specifications written on tests from this sample limit the source of the crude from which the specification oil can be made. This may be desired, but such a condition prevents receiving the benefit of the constant improvements which are being made by the different lubricating oil manufacturers, in the oils made from the various crudes.

WRITING SPECIFICATIONS.—If specifications are desired, they should not be too closely written. Their purpose should be to secure a satisfactory oil for fulfilling certain conditions, at the lowest competitive prices, and should not be written with the view of excluding oils made from crudes other than that of the tested sample.

An exactly stated gravity, viscosity, and flash will pin all bidders to very narrow limits. Gravity is of no importance, except in special cases. Lubrication depends upon viscosity and its characteristic variations.

HINTS FOR WRITING SPECIFICATIONS.—For general lubricating requirements, such as motors, gas engines, turbines, machine bearings, mechanical prime movers, etc., there is no need to include a gravity specification. It must be clearly understood that the following listed

---

* Note. The best results for economy and efficiency will be obtained by having experienced industrial oil engineers survey the equipment and processes, and then prepare specifications for products to meet the operating requirements. These specifications must be written, to encourage competition and with a full knowledge of oil conditions.

specifications are merely suggestions, and that no attempt is made to lay down definite specifications, because such a plan would be impossible. The crude sources from which the oils are made are constantly changing. the design of machinery improves, and the method of applying the lubricant is bettered, constantly. Bearing these points in mind, the reader may get some suggestions from the following:

THE IMPORTANT POINTS TO COVER.—

A

1. *Viscosity,* Saybolt, at 100° Fahr., for turbine, general machine, air compressor, air cylinder, air compressor bearings, ice machine, marine engine; paraffin, neutral, transformer, crank-case, Diesel engine, spindle, loom, cutting, textile, absorption, washing, heat treatment, etc., oils.

B

Viscosity, Saybolt, at 130° Fahr., for winter black oil.

C

Viscosity, Saybolt, at 212° Fahr., for steam cylinder and summer black oils, heavy quenching oils, and extra heavy motor cylinder oils.

D

Viscosity for some oils, such as turbine and circulating system oils, to be given at the running temperature of the bearings, as well as at 100° Fahr. It may be desirable in some cases to specify the viscosity of A-type oils at a temperature of 130° Fahr.

2. *Flashing Point,* Open Cup—Cleveland Tester (if desired, the flashpoint may also be given as determined in the Pensky-Martens closed-cup instrument) for all oils, including quenching, tempering, process and trade oils.

3. *Cold Test.*—Describe the method used to make the cold test; also state whether it is a cloud or pour test.

Give cloud test for paraffin oils, paraffin engine oils, and other oils from paraffin and semi-paraffin crudes.

Give pour test for paraffin oils, paraffin engine oils, steam cylinder oils, asphalt-base oils, marine engine oils, spindle oils, turbine oils, ice-machine oils, etc.

4. Give *demulsibility* test for turbine, transformer, continuous feed system oils, neutral oils for trade purposes, oils for ring or chain feed, forced-feed oils in general. These oils should have a good demulsibility test to indicate that they will throw off moisture and not cause trouble by emulsifying.

Also give demulsibility tests for marine engine oils, paraffin oils, oils for trade purposes requiring emulsification, and other oils that are intended to easily emulsify. These oils should have a low demulsibility.

5. Give *Compound.*—The trade name and quality of the oil, or other compound to be used. The per cent. of the compound by volume should be given.

6. For some oils, such as transformer, continuous oiling-system oils, etc., a test, limiting the *loss permitted in the oil after heating* for a stated time at a definite temperature, should be included.

Usually a temperature, approximating the temperature of the bearings, or other apparatus requiring the oil, is taken as the heating temperature, and a factor of safety added.

TYPICAL PHYSICAL AND CHEMICAL LUBRICATING OIL TESTS

NOTE. All oils to be free from mineral acids, soap, asphalt, tarry matter, and excess fatty acid.

(1) Air Compressors:

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
	PRESSURES UP TO 125 POUNDS PER SQUARE INCH		
400+	160–170@100° F.	30	(P. B.)
325+	200–250@100° F.	0	(A. B.)
	HIGH PRESSURES AND FOR ROLLING TYPE VALVES		
525+	300–325@100° F.	35	(P. B.)
2) Black Oils: (Grav. may be stated)			
325+	65–90@212° F.	40	(Summer Black)
360+	35–80@212° F.	10–30	(Winter Black)

(3) Cylinder Oils (Steam Engine)

(a) Low steam pressures, long steam pipe, wet steam			
490+	145–155@212° F.		6–8% Acidless Tallow
(b) Medium steam pressures, 100 to 150 pounds			
530+	150–160@212° F.		6% Acidless Tallow
(c) Med. high steam pressures, 150 to 175 pounds, dry steam			
560+	160–160@212° F.		5% Acidless Tallow
(d) High steam pressure (175 and up), dry steam			
600+	190–210@212° F.		5% Acidless Tallow
(e) Superheated steam			
625+	335–350@212° F.		No compound
(f) For low pressure cylinders, Compound and Triple Expansion Engines			
500+	130–145@212° F.		8% Acidless Tallow

(g) For steam cylinders, where the exhaust steam is used for making ice, drying, heating and where the boiler feed is drawn from the hot well, govern the flash and viscosity, as indicated above, to meet the steam conditions, but do not use any compound, if possible.

Cylinder oil (ammonia ice machine cylinders)			
360+	100–120@100° F.	0–10	(P. B.)
325+	200–210@100° F.	0	(A. B.)

(4) Crank-case Oils:

440+	470–490@100° F.	45	Demulsibility, Zero

(5) Engine and Dynamo Oils, Etc.

(a) For engines running at 150–300 r.p.m., snug bearings, etc.

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
		NO FILTERING	
375+	140–150@100° F.	35	(P. B.) Paraffin Oil
325+	200–210@100° F.	10	(A. B.)
	FILTERING AND CIRCULATING SYSTEM		
390+	140–150@100° F.	35	(P. B.) Neutral Oil. Demulsibility 300+
325+	200–210@100° F.	10	(A. B.) Non-emulsifying, or, demulsibility 300+

(b) For engines running at 125–150 r.p.m.

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
		NO FILTERING	
400+	260–270@100° F.	35	(P. B.) Paraffin Oil
335+	300–310@100° F.	0	(A. B.)
	FILTERING AND CIRCULATING SYSTEM		
390+	170–180@100° F.	35	(P. B.) Neutral Oil. Demulsibility 300+
335+	300–310@100° F.	0	(A. B.) Demulsibility 300+

(c) For engines and dynamos and machinery running 75 to 125 r.p.m.

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
		NO FILTERING	
400+	290–300@100° F.	40	(P. B.) Paraffin Oil
345+	400–450@100° F.	0–10	(A. B.)
	FILTERING AND CIRCULATING SYSTEM		
425+	200–210@100° F.	40	(P. B.) Neutral, Demulsibility 300+
345+	375–400@100° F.	0–10	(A. B.) Demulsibility 300+

(6) Gas and Gasoline engines:

Maximum carbonization .15% (Bureau of Standards method, reprint 160)
Should not require more than .05 milligram KOH to neutralize one gram.

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
(a) Light			
400+	145–150@100° F.	30	(P. B.)
325+	195–200@100° F.	0–10	(A. B.)
(b) Medium			
400+	200–210@100° F.	30	(P. B.)
335+	300–310@100° F.	0–10	(A. B.)
(c) Heavy			
400+	290–300@100° F.	35	(P. B.)
350+	450–475@100° F.	0–10	(A. B.)
(d) Extra Heavy			
400+	400–410@100° F.	40	(P. B.)
350+	700–725@100° F.	0–10	(A. B.)

(7) Marine Engine Oils

Flash Fahr.	Vis. Saybolt	Cold Test	Notes
		STRAIGHT MINERAL OILS	
450+	370–380@100° F.	40	(P. B.) Paraffin Oil or Special Treated
350+	500–510@100° F.	0–10	(A. B.) Special Treated

Flash Fahr.	Vis. Saybolt	Cold Test	(Compound)
			COMPOUNDED OILS
400+	565–575@100° F.	40	(P. B.) 15–20% Blown Rape or Blown Cottonseed Compound
350+	700–710@100° F.	40	(A. B.) 15–20% Blown Rape or Blown Cottonseed Compound

(8) **Turbine Oils**

Use the same specifications as for high speed engine oils, intended for circulating system use and filtering.

(9) **Transformer Oils**

Demulsibility tests (Bureau of Standards) should be 1200.
No moisture permitted in oil. Not more than 2% evaporation loss when heated to 190° Fahr.
Flash-point should be about twice the temperature limit of the transformer.
See index for more complete transformer oil specifications.

SECTION 11a
LUBRICATION COST

THE COST OF LUBRICATION

The "*cost of lubrication*" is closely connected with the "*cost of power*" and operation of all power plants and mills. In the average plant, large savings may be effected in the cost of power by expending thought and care in the selection, purchase, and application of the proper lubricants to the prime movers, transmission shafting, and individual machines.

In factories and mills using individual motor drives on the various units, the necessity for the reduction of the friction loads of the transmission shafting is, of course, eliminated. There are, however, great possibilities for reducing the friction loss in the prime mover and the electric generator, with a resulting reduction in the cost per kilowatt for the power supplied to the various units. Reductions in the friction loads, of the various motor-driven units, may be easily detected by the use of instruments for measuring the power input to the machines.

Competent industrial oil engineering supervision will produce marked improvements from the economical and efficiency standpoints.

Outline of Method to be Used for the Selection and Purchasing Lubricants

The steps necessary to secure the most efficient and economical lubrication of a plant may be outlined as follows:

1. Study the mechanical and physical conditions which directly or indirectly affect the lubrication of the plant.

2. Select a lubricant, or lubricants, that will satisfy the determined mechanical and physical conditions, *economically* and *efficiently*.

3. Check up all deliveries of the lubricants, as to uniformity and correct gallonage. (See index for Method of Checking Deliveries by Weight.)

No plant is so small that it can afford to give any less consideration to checking the deliveries of the proper and full amounts of gallonage as paid for, than is given to noting whether the employees report on time for work, or only work half a day and receive pay for a full day.

4. Apply the lubricants efficiently, by means of suitable distributing appliances, to the exact surfaces requiring lubrication.

5. Provide suitable arrangements for collecting and recovering the used oil, if possible, and settle and filter it for reuse.

A properly designed lubricating system will soon pay for itself, by reducing the amounts of oil used and by giving uniform and effective lubrication.

6. Particularly in large plants, and generally in the average-sized mill, one man should be put in charge of the oil and grease stores. When lubricants are issued, a careful record should be kept, showing who received them and what use was made of them. Careless and wasteful employees and worn-out and inefficient machinery may thus be easily detected. (See index for Oil-house Methods.)

THE COST OF LUBRICATION

The cost of lubrication must include not only the actual cost of the lubricants, but also the cost of power, necessary to overcome that friction load and wear and tear on the machinery, which can be traced to faulty lubrication.

A comparative cost of lubrication, as obtained with various lubricants, may be determined by the following formula:

D = Dollars saved per year with lubricants under investigation, as compared with other lubricants.
F_s = Horse-power saved, due to decreased friction.
R_s = Repair saving and depreciation reduction per year, directly traceable to lubrication.
L = Total net cost of lubricants per year, taking into account the amounts bought and the amounts recovered and reused.
H = Cost per year of one brake horse-power.

$$D = (H \times F_s) + R - L$$

Of several lubricants compared with this formula, those having the highest value of D are the most efficient and economical.

The "*cost of lubrication*" may, therefore, be reduced, by obtaining the results as summarized in the following outline:

1. *By reducing the frictional power losses in the prime mover:*
   Frictional losses in a prime mover may be as high as 20 per cent. of the power supplied to it. In modern high-speed engines, this loss may be reduced to 3 per cent. or 4 per cent., and the older types of engines to 6 per cent. or 8 per cent., by efficient lubrication. (As pointed out in another section of this book, it costs the larger producer of power about $15 per year per horse-power, and the small producer up to about ten times that amount.) The possibilities of effecting a saving are evident.
2. *By reducing the friction losses of the transmission shafting:*
   Shafting losses often run as high as 60 per cent. of the power transmitted to it, averaging about 35 per cent. It is possible to reduce this loss to about 10 per cent. Often as high as 40 per cent. savings have been effected in the friction losses of transmission shafting by changing the grade of the lubricant. Of course, proper alignment, ring oilers, and properly adjusted belting play a most important part in shafting friction losses.
3. *By reducing the frictional losses in the individual machines:*
   Practical tests on various machines show frictional losses, ranging from 10 per cent. to 50 per cent. of their full load power. In large mills particularly, even a small reduction in the frictional loss per machine will effect a large total saving in the plant.
4. *By decreasing the cost of repairs and depreciation:*
   Repairs average from 5 per cent. to 25 per cent. of the total cost of power.
5. *Depreciation* of plant equipment is usually figured at the rate of 20 per cent. to 30 per cent. per year, of the cost of producing

power. That is to say, at the end of ten years the average industrial machine must be renewed. If the wear and tear on the machine is decreased, it is evident that this large depreciation charge can be reduced, with a consequent reduction in the cost of power.

There is, however, one part of the depreciation charge which cannot be decreased by any method. This is that depreciation which is due to the improvements that are constantly being made in machinery, which compel the manufacturer to install new machinery to keep up to the highest types of improved machinery in his line.

6. Considered from the standpoint of ultimate economy, the actual cost of lubricating oils and greases necessary to produce good lubrication is insignificant, when compared with the large saving in power costs resulting from their use.

DEPRECIATION COST OF LUBRICATING OILS

INVESTIGATION OF LUBRICATING OILS BY FRACTIONAL DISTILLATION.—With a view to investigating the properties of asphalt-base oils and paraffin-base oils, with respect to the relations between viscosity, flash-point, specific gravity, and volatility of their component fractions, a comprehensive series of tests was made by the Engineering Experiment Station of the United States Navy at Annapolis, Md.

The results of some of these tests were reported by Mr. J. G. O'Neill, a chemist at the station, in a recent issue of the *Journal of the American Society of Naval Engineers.* The author was also in touch with these tests to some extent, and a description of the partial results is given as follows:

The purpose of the tests was to separate the mineral lubricating oils into their component light, intermediate, and heavy oils, and to investigate the properties of the various fractions. Great care was taken to prevent the decomposition of the component oils, and by reuniting the component parts the original oil could be generally obtained. The fractional distillation was carried out by the use of heat and superheated steam. The laboratory apparatus was carefully planned and gave accurate results.

The fractions were made as nearly equal in weight as possible, and there were usually four or five of these fractions.

The oils tested were straight mineral oils and may be listed as follows:

1. Light forced-feed oil	Asphalt base
2. Medium forced-feed oil	Paraffin base
3. Medium forced-feed oil	Asphalt base
4. Medium forced-feed oil	Asphalt base
5. Medium forced-feed oil	Paraffin base
6. Light forced-feed oil	Asphalt base
7. Ice-machine oil	Asphalt base

The viscosities, flash-points, fire-points, and specific gravities of the original oils and their fractions were taken.

The original sample of oil taken for test was about 600 c.c., and this allowed five fractions of about 120 c.c. each.

The following table shows some of the results:

Number of oil	Fraction	Per cent. total	Vis. Say. at 100° Fahr.	Flash, Fahr.	Baumé gravity	Fire-point
1	Original	.....	199.0	312	19.4	364
	A	17.38	64.8	273	22.6	300
	B	22.32	108.5	328	20.5	362
	C	20.10	202.4	360	19.4	408
	D	22.78	428.5	408	18.6	458
	E	17.42	2,581	404	17.5	440
2	Original	.....	205.0	395	27.8	455
	A	18.31	99.6	326	29.7	360
	B	18.38	128.0	390	29.0	414
	C	18.49	164.0	388	28.6	405
	D	19.64	250.3	388	27.1	412
	E	25.18	619.8	453	25.5	486
3	Original	.....	275.0	354	20.0	392
	A	27.23	91.2	316	21.3	338
	B	24.17	190.0	372	20.5	398
	C	28.39	414.0	390	19.7	405
	D	20.21	2,358	404	18.5	446
4	Original	.....	316.0	348	21.0	384
	A	24.39	98.1	305	23.0	328
	B	22.30	197.2	358	21.85	383
	C	24.81	445.0	392	21.0	430
	D	28.50	1,402	438	20.0	450
5	Original	.....	255.0	410	24.8	436
	A	22.48	126.2	338	26.2	362
	B	22.27	179.2	407	25.5	435
	C	20.97	248.0	427	24.8	442
	D	34.28	603.0	444	23.2	468
6	Original	.....	178.0	403	28.5	464
	A	21.95	108.0	350	29.4	390
	B	24.23	140.2	368	29.5	405
	C	22.83	185.0	374	29.0	405
	D	30.99	380.0	444	26.9	468

The investigation, according to Mr. O'Neill, indicates several very important facts. Instead of a lubricating oil being composed of several oils having practically the same viscosity, it is composed of a large number of oils having a wide range of viscosities, and the viscosity of the oil, as known to the trade, is an average viscosity of all the component viscosities.

An analysis of the preceding table shows the following results in tabulated form:

Oil number	Percentage composition by weight			Base of oil, grade
	Viscosity below 140	Viscosity 140 to 500	Viscosity above 500	
	Per cent.	Per cent.	Per cent.	
1	38.5	38.5	23.0	Light, asphalt.
2	30.5	54.5	15.0	Medium, paraffin.
3	29.0	43.0	28.0	Medium, asphalt.
4	25.0	39.5	35.5	Medium, asphalt.
5	17.0	63.0	20.0	Medium, paraffin.
6	36.0	74.0	00.0	Light, paraffin.

The conclusions drawn by Mr. O'Neill are as follows:

Light oils, having a viscosity below 140° Say., are not desirable for use in the lubrication of machinery, because they are exposed to conditions of heat, steam, and agitation, which rapidly vaporize them.

Heavy oils, above 500° Say. Vis., are undesirable, because they are more liable to decomposition than are oils of lighter viscosity, and on decomposition produce tarry or carbon deposits.

When heavy oils and light oils are mixed and give a medium oil, the viscosity of this oil is subject to a more rapid change than is a medium oil composed of closer fractions.

The life of a lubricating oil in service can be estimated, and those oils containing the largest percentage of component parts having viscosities between 140° and 500° Say. will give longer service than will those oils that are low in these fractions.

It is to be noted that for the same viscosity, the asphalt-base oils are more volatile than are the paraffin-base oils.

The recommendation is made that mineral oils should be compounded from oils which have narrow limits of vaporization temperatures, and that the oils should have as near as possible the same viscosity and gravity.

COMPARISON OF ULTIMATE ECONOMY OF LUBRICATING OILS

It has been practically impossible in the past to accurately compare the oils made from asphalt- and paraffin-base crudes, with a view towards determining the actual amount of lubrication which is obtained per gallon from the oils, in the same class of service.

Undoubtedly a mechanical study of the actual component parts of the oils, recommended for the same purposes, but made from different crudes and having widely separated physical characteristics, can be developed to such a point that it will be possible to buy lubrication with as much intelligence as is now possible in the purchase of steel or coal.

Viewing the subject from another standpoint, if ten tons of lubricating oil are bought, and after a thousand hours' use the oil has lost a tenth of its weight by vaporization, while with another oil this loss would only have been one-twentieth of its original weight, then it is not correct to compare these oils on the basis of their actual cost per gallon or friction-reducing qualities alone, but we must also take the *depreciation cost* of the oils into consideration.

It is, therefore, strongly recommended that the present physical tests and practical friction and operating tests be completed by a *depreciation test*, and that some standard method be laid down for conducting these tests.

SECTION 11b

LUBRICATING ENGINEERING REPORTS

The lubricating engineering department of all oil companies should be equipped with a standard form, on which the field engineers can submit their reports of inspections. These reports will form the basis of interesting data for future reference and at the same time will place before the man in the office a concrete picture of the lubricating conditions existing in the plants visited.

For illustrative purposes, the following forms are given. They are in use by two large oil companies.

The following set of three forms is given as an illustration of a simple form adopted for a power-plant inspection:

THE OIL REFINING CO.

Lubrication Engineering Department

LUBRICATION DATA

PLANT .... **DATE**................

ADDRESS ....

CHARACTER OF BUSINESS ....

POWER ....

Generated—How? ....

Bought—Kind? ....

Amount........ **H. P. (K. W.) hours per day of**........**hours**.........

How Transmitted? ....

How Used? ....

LUBRICANTS

Consumption per Annum: Total......**bbls.; Cylinder Oils**......**bbls.;**
Engine Oils......**bbls.**

Machine Oils......**bbls.; Misc. Oils**......**bbls.; Greases**......**bbls.**

Methods of Application: ....

Type of Lubricators? ....

Rate of Feed: Cylinder Oils..............**Engine Oils**..............

Machine Oils......................**Misc. Oils**........................

Filter System—Kind? ....

Oil Atomizer—Kind? ....

Unfiltered Oil Used—for what? ....

STEAM

Pressure at Power Units?.........**Condition at Power Units?**.........

Super-heated—Degrees?..........**Back Pressure?** ....

Boiler Water—Source?...........**Treated?**.........**Condition?**........

REMARKS: (Give condition of atmosphere, machinery, etc.)

....

....

Inspection by,

....

THE OIL REFINING CO.
Lubrication Engineering Department

POWER UNITS

Prime Movers, Transmission, Mfg. Machines, Etc.

PLANT........................ DATE.................

Following description of each unit or group give lubricant consumption, method of feed, type of drive (belted or direct-connected), etc.

Class	Make and type	Size	Rated H. P.	Speed	Temp. ° F.	Pressure		Load factor
						Steam	Air	

THE OIL REFINING CO.
Lubrication Engineering Department

REQUIREMENTS AND RECOMMENDATIONS

PLANT......................... **DATE.................**

Group units of like class. State requirements fully for individual units. Keep number of different recommendations at minimum consistent with maximum efficiency and practicability.

Unit	Requirements	Recommendation

Remarks

Recommendations by,

____

Checked by ________________________

The following forms illustrate a complete series of reports used for reporting and tabulating a power-plant and oil survey:

Sheet 1

PLANT-INSPECTION REPORT

Firm name..Business........................

Town of.................................County.............State..............

Party interviewed..............................Title............................

NAMES OF OFFICIALS AND TITLES

.....................................Engineer ....Superintendent

....Buyer...................................

GENERAL INSTALLATION

Number of steam engines "main units"	....	Total rated horse-power	....
" " " " "auxiliaries"	....	" " " "	....
" " " turbines	....	" " K. W.	....
" " " locomotives	....	" estimated horse-power	....
" " " shovels	....		....
" " gas engines "main units"	....	" rated horse-power	....
" " " " "auxiliaries"	....	" " " "	....
" " oil "	....	" " " "	....
" " air compressors	....	" estimated	....
" " electric generators	....	" " K. W.	....
" " " motors	....	" " H. P.	....
" "	....	....	
" "	....	....	

From whom buying ....Under contract ....Expires........

DETAILS COVERING YEARLY CONSUMPTION

Products	Buying From This Co.			Buying From Others				Buying Total Bbls. per yr.
	Brands	Bbls. per yr.	Price	Firm Name	Brands	Bbls. per yr.	Price	
Black oils								
"								
Engine "								
"								
"								
Steam cyl. "								
"								
"								
"								
Totals "								
Cup grease								
"								
"								

Date....................19.. Signed..................................

Sheet 2

Firm name.................................. Town of............. ......19....

Details of Reciprocating-Steam-Engine Installation

Builders' name	....	....
Type of engine; simple, twin, compound or tandem-compound, etc.	....	....
Vertical or horizontal	....	....
Type of valves; slide, Corliss or piston, etc.	....	....
Size of bore and piston stroke, in inches	....	....
Horse-power, total rated	....	....
" " maximum load	....	....
" " minimum load	....	....
Speed, revolutions per minute	....	....
Steam pressure at boiler, pounds per square inch	....	....
" " " throttle " " " "	....	....
" quality at throttle, if saturated, state whether wet or dry	....	....
" " " " " superheated " degrees of superheat	....	....
Condensing or non-condensing	....	....
What becomes of the exhaust steam? Heating? Laundry? etc	....	....
" " " " condensed " Returned to boilers? Ice making?	....	....
Method of internal lubrication, hydrostatic or force-feed lubricators	....	....
State if splash type	....	....
Method of external lubrication, sight-feed cups or circulating system	....	....
Where is cylinder oil introduced? Directly into steam chest, over valves? Or if into steam line, where?	....	....
Is filter used? Give name, also state whether wet or dry type	....	....
Is water separator used? State where located	....	....
If compound engine, is same cylinder oil used in both high- and low-pressure cylinders	....	....

Details of Steam-Turbine Installation

Make of turbine	....	....
Vertical or horizontal	....	....
Power, rated K. W. (kilowatts)	....	....
Speed, revolutions per minute	....	....
Has turbine a reduction gear?	....	....
Quantity of oil lubricating system holds	....	....
Type of filters used, batch or continuous	....	....

Details of Lubricating Oils Used

	Cylinder Oils	Engine Oils	Turbine Oil
Brands in use	....	....	....
Brand recommended	....	....	....
Price made on oil	....	....	....

If two or more different cylinder oils, engine or machine oils are used, then show on Sheet 4 the purpose for which each different one is used.

(Where units differ, report in separate column upon each different unit.)

Sheet 3

Firm name.................................Town of................. ......19...

DETAILS OF GAS-ENGINE INSTALLATION

Builders' name	....	....
Type of engine; single, twin, tandem or twin-tandem?	....	....
2 or 4 cycle	....	....
Vertical or horizontal	....	....
Number of cylinders	....	....
Size of bore and piston stroke in inches	....	....
Horse-power, total rated	....	....
Are engines operated continuously, or, if not, how much?	....	....
Speed, revolutions per minute	....	....
Degrees F. of jacket water	....	....
Method of bearing lubrication, sight-feed cups, circulating system or splash	....	....
Method of cylinder lubrication, gravity, mechanical or splash	....	....
For what work is engine power used?	....	....

DETAILS OF OIL-ENGINE INSTALLATION

Builders' name	....	....
Type of engine, state if crank-case	....	....
2 or 4 cycle	....	....
Vertical or horizontal	....	....
Number of cylinders	....	....
Size of bore and piston stroke in inches	....	....
Horse-power, total rated	....	....
Speed, revolutions per minute	....	....
Give pressure of air used in connection with engine	....	....
Is same lubricating oil used for cylinder and crank-case?	....	....
Is water used to float lubricating oil in crank-case?	....	....

DETAILS OF AIR-COMPRESSOR INSTALLATION

Make of compressor	....	....
Type of " 1-2-3 or 4 stage	....	....
Size of bore and piston stroke in inches and, if multiple stage, give bore in inches of each cylinder	....	....
Is compressor steam, gas or electrically driven	....	....
Speed, revolutions per minute	....	....
Pounds pressure of air generated	....	....
Are there auxiliary compressors not water cooled?	....	....
Is lubrication gravity or mechanical feed?	....	....
What is air used for? Air blast, locomotive, tools, etc.	....	....
(Cover driving-power installation under its proper heading.)		

DETAILS OF LUBRICATING OILS USED

	Gas-engine Oil	Oil-engine Oil	Air Compressor
Brands in use	....	....	....
Brand recommended	....	....	....
Price made on oil	....	....	....

If two or more different cylinder oils, engine or machine oils are used, then show on Sheet 4 the purpose for which each different one is used.

(Where units differ, report in separate column upon each different unit.)

Sheet 4

Firm name.................................... ....19.....

DETAILS OF MISCELLANEOUS EQUIPMENT AND GENERAL REMARKS

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SECTION 11c

U. S. GOVERNMENT SPECIFICATIONS (LUBRICANTS)

METHODS OF TESTING LUBRICANTS

Adopted by the Committee on Standardization of Petroleum Specifications.

The following specifications were issued by the above committee, April 16, 1920, acting under authority conferred by order of the President.

FLASH-POINT.—This test shall be made in the Cleveland Open Cup Tester, the apparatus being used without any bath or outer cup surrounding the oil cup. The oil cup should have two marks on the inside, the first, one-quarter inch below the top, and the second, three-eighths inch below, the first to be used when testing oils with a flash-point below 425° F. and the second when testing oils with a flash-point at or above 425° F. The clean oil cup should be inserted into the tripod ring, which must be level, and the cup filled to the proper mark with the oil to be tested. Care should be exercised not to spill any oil on the sides or top of the cup, and if this accident should happen, all such oil must be carefully removed. A " bulb immersion " thermometer should then be inserted into the oil and suspended from a suitable support. The bulb of the thermometer should be three-eighths to five-eighths inch in length. During the test the bulb must be fully covered by the oil and the bottom of the thermometer must not be less than one-fourth inch from the bottom of the cup. The thermometer must be suspended in the oil midway between the centre and inside edge of the cup. The alcohol or gas burner is then placed under the oil cup so as to heat it uniformly. The oil may be heated rapidly at first, but the rate of heating should be 8 to 10 degrees F. (5° C.) per minute during the last 80 degrees of heating prior to attaining the flash-point. As the flash-point is approached, a test is made for every 5 degrees F. rise in temperature (on the readings, which are multiples of 5) by slowly passing a small bead-like test flame, not exceeding one-eighth inch in length, across the centre of the cup one-fourth inch above the surface of the oil, the movement occupying one second.

The temperature when a flame first jumps from the test flame to the oil is called the flash-point of the oil. The test must be made where the cup is free from draughts, and must also be made in a subdued light.

FIRE-POINT.—After the flash-point has been obtained, the same method of testing shall be continued until the oil takes fire and continues to burn. The temperature at which the oil continues to burn is the fire-point of the oil.

VISCOSITY. A. S. T. M. METHOD D47-19T.—Viscosity shall be determined by means of the Saybolt Standard Universal Viscosimeter, as described in the *Proceedings of the American Society for Testing Materials,* Vol. xix, Part 1, page 728, 1919.

Viscosity shall be determined at 100° F. (38.8° C.), 130° F. (54.4° C.), or 210° F. (98.9° C.). The bath shall be held constant within 0.25° F. (0.14° C.) at such a temperature as will maintain the desired temperature in the standard oil tube. For viscosity determinations at 100° and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at 210° F., oil shall be used as the bath liquid. The oil for the bath liquid should be a pale engine oil of at least 350° F. flash-point (open cup). Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the standard oil tube. either for cleaning or for test, shall first be passed through the strainer.

To make the test, heat the oil to the necessary temperature and clean out the standard oil tube with the plunger, using some of the oil to be tested. Place the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube. The stopper should be sufficiently inserted to prevent the escape of air, but should not touch the small outlet tube of the standard oil tube. Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined, and pour it into the standard oil tube until it ceases to overflow into the overflow cup. By means of the oil tube thermometer keep the oil in the standard oil tube well stirred and also stir well the oil in the bath. It is extremely important that the temperature of the oil in the oil bath be maintained constant during the entire time consumed in making the test. When the temperature of the oil in the bath and in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60 c.c. flask in position so that the oil from the outlet tube will flow into the flask without making bubbles; snap the cork from its position and at the same instant start the stop watch. Stir the liquid in the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60 c.c. of oil is the Saybolt viscosity of the oil at the temperature at which the test is made.

VISCOSITY. A. S. T. M. METHOD (Revised in 1920).—(Received after the Methods of Testing Lubricants were adopted by the Committee.)

1. Viscosity shall be determined by means of the Saybolt Standard Universal Viscosimeter.

2. (*a*) The *Saybolt Standard Universal* Viscosimeter (see Fig. 1, Sec. 11c) is made entirely of metal. The standard oil tube *A* is fitted at the top with an overflow cup *B*, and the tube is surrounded by a bath. At the bottom of the standard oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask (Fig. 2, Sec. 11c), whose capacity to a mark on its neck is 60 (± 0.15) c.c. The lower end of the outlet tube is enclosed by a larger tube, which, when stoppered by a cork, *C*, acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped string may be attached to the lower end of the cork as an aid to its rapid removal. The temperature in the standard oil tube and in the bath are shown by thermometers. The

bath may be heated by any suitable means. The standard oil tube shall be thoroughly cleaned, and all oil entering the standard oil tube shall be strained through a 60-mesh wire strainer. A stop watch shall be used for taking the time of flow of the oil, and a pipette shall be used for draining the overflow cup of the standard oil tube.

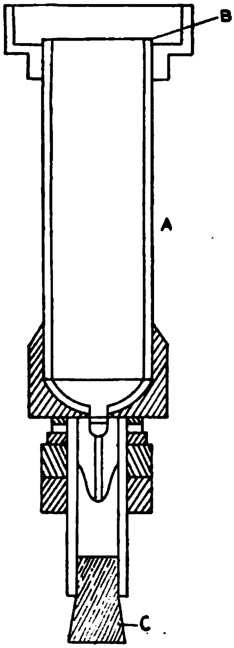

FIG 1. SEC. 11c.—Sectional view of standard oil tube.

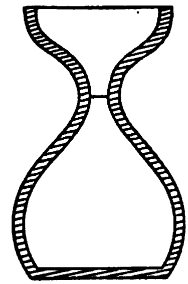

FIG. 2. SEC. 11c.—Sectional view of receiving flask.

(*b*) The *standard oil tube,* which may be standardized by the U. S. Bureau of Standards, Washington, D. C., shall conform to the following dimensions:

Dimensions	Minimum, cm.	Normal, cm.	Maximum, cm.
Inside diameter of outlet tube	0.1750	0.1765	0.1780
Length of outlet tube	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube	12.40	12.50	12.60
Diameter of container of standard oil tube	2.955	2.975	2.995
Outer diameter of outlet tube at lower end	0.28	0.30	0.32

3. *Viscosity* shall be determined at 100° F. (37.8° C.), 130° F. (54.4° C.), or 210° F. (98.9° C.). The bath shall be held constant within 0.25° F. (0.14° C.) at such a temperature as will maintain the desired temperature in the standard oil tube. For viscosity determinations at 100° F. and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at 210° F., oil shall be used as the bath liquid. Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the standard oil tube, either for cleaning or for test, shall first be passed through the strainer.

To make the test, heat the oil to the necessary temperature and clean out the standard oil tube. Pour some of the oil to be tested through the cleaned tube, insert the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube, sufficiently to prevent the escape of air, but not to touch the small outlet tube of the standard oil tube.

Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined, and pour it into the standard oil tube until it ceases to overflow into the overflow cup. By means of the oil tube thermometer keep the oil in the standard oil tube well stirred, and also stir well the oil in the bath. It is extremely important that the temperature of the bath be maintained constant during the entire time consumed in making the test. When the temperature of the bath and of the oil in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60 c.c. flask, Fig. 2, Sec. 11c, in position so that the stream of oil from the outlet tube will strike the neck of the flask so as to avoid foam. Snap the cork from its position, and at the same instant start the stop watch. Stir the liquid in the bath during the run, and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60 c.c. of oil is the Saybolt viscosity of the oil at the temperature at which the test was made.

POUR TEST. A. S. T. M. METHOD D47-18.—1. The pour test indicates the temperature at which a sample of oil in a cylindrical container of specified diameter and length will just flow under specified conditions.

2. *Apparatus:* The apparatus for the pour test consists of the following:

(*a*) Glass jar, approximately 1 1/4 inches inside diameter and 4 to 5 inches high, provided with a tightly fitting cork.

(*b*) Mercury thermometer, fitted securely in the cork so that the shaft will be held centrally in the jar with the tip of the bulb 1/2 inch from the bottom. The thermometer specially made for this test has a bulb 1/4 to 3/8 inch long.

(*c*) Metal jacket, closely fitted around the glass jar and provided at the bottom with a disc of cork felt about 1/4 inch thick.

3. *Method:* Place the oil in the jar to a depth of about 1 1/4 inches, or to a sufficient depth to reach 1/4 inch above the bulb of the thermometer; fit the cork tightly into the jar and place the jar in the metal jacket; then place the jacket in a freezing mixture. At each drop in temperature of 5 degrees F. (on the readings which are multiples of 5 degrees) remove

the jar from the jacket and tilt it just enough to make the oil flow. The pour test of the oil shall be taken as 5 degrees higher than the reading of the thermometer when the oil has cooled so that it will not flow when the jar is tipped to a horizontal position.

4. The rate of cooling should be such that the pour test be completed in about one-half hour.

5. The *materials* used in the freezing mixture vary with the temperature required to cause the lubricant to solidify. Cracked ice will be sufficient for a temperature above plus 35° F. For temperatures between plus 15° F. and plus 35° F. a mixture consisting of 1 volume of salt and 20 volumes of ice may be used. The salt for this purpose should be very dry and fine enough to pass a 20-mesh screen. From plus 15° to minus 5° F. ice and salt in the proportions of one to two are suitable. From 0° to –25° F. a mixture of ice and calcium chloride is used. For temperatures lower than –5° F. a mixture of solid carbon dioxide and acetone is more convenient and will produce temperatures of –70° F. or less.

6. To obtain the solid carbon dioxide, invert an ordinary liquefied carbon dioxide cylinder, open the valve carefully and let the gas flow into a chamois-skin bag. Rapid evaporation will cause the carbon dioxide to solidify.

7. The carbon dioxide-acetone mixture may be made as follows:

Place a sufficient amount of dry acetone in a covered copper or nickel beaker; place the beaker in an ice-salt mixture, and when the acetone reaches plus 10° F. or less, add solid carbon dioxide gradually until the desired temperature is reached.

COLD TEST FOR STEAM CYLINDER AND BLACK OILS. A. S. T. M. METHOD D47-18.—The object of the cold test is to determine the lowest temperature at which oil will flow from one end of a container to the other, in case it should become frozen and the resulting solid oil stirred till it has assumed a sufficiently pasty consistency to flow. The test is conducted by freezing an ounce of the oil solid in an ordinary 4-ounce sample bottle, using a freezing mixture if necessary. A thermometer should then be introduced into the frozen mass, and after it has become cold, the bottle containing the congealed oil is removed from the cooling medium. The frozen oil is thoroughly stirred with a thermometer until the mass will run from one end of the bottle to the other, and at this moment the temperature as indicated is recorded. The reading is the cold test of the oil.

If the figures indicating the cold test are inside the bottle and covered by the softened oil, the reading can be obtained by grasping the bottle by the neck with one hand, having in the same hand a piece of waste, which incloses the thermometer. The thermometer is then withdrawn through the waste with the other hand for a sufficient distance to enable the operator to see the end of the mercury column and read the temperature.

CARBON RESIDUE. A. S. T. M. METHOD D47-18.—*Apparatus:* (*a*) Porcelain crucible, wide form, glazed throughout, 25 to 26 c.c. capacity, 46 mm. in diameter.

(*b*) Skidmore iron crucible, 45 c.c. (1 1/2 ounce) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

(*c*) Wrought-iron crucible with cover, about 180 c.c. capacity, 80 mm.

diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep, or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought-iron crucible.

(*d*) Triangle, pipe stem covered, projection on side so as to allow flame to reach the crucible on all sides.

(*e*) Sheet iron or asbestos hood provided with a chimney about 2 to 2 1/2 inches high, 2 1/8 inches in diameter, to distribute the heat uniformly during the process.

(*f*) Asbestos, or hollow sheet-iron block, 6 to 7 inches square, 1 1/4 to 1 1/2 inches high, provided with opening in centre 3 1/4 inches in diameter at the bottom and 3 1/2 inches in diameter at the top.

Method: The test shall be conducted as follows:

Ten grams of the oil to be tested are weighed in the porcelain crucible (*a*), which is placed in the Skidmore crucible (*b*), and these two crucibles set in the larger iron crucible (*c*), being careful to have the Skidmore crucible set in the centre of the iron crucible, covers being applied to the Skidmore and iron crucibles. Place on triangle and suitable stand with asbestos block, and cover with sheet-iron or asbestos hood in order to distribute the heat uniformly during the process.

Heat from a Bunsen burner or other burner is applied with a high flame surrounding the large crucible (*c*) until vapors from the oil start to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over 2 inches above the sheet-iron hood. After the vapor ceases to come off the heat is increased as at the start and kept so for five minutes, making the lower part of large crucible red hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a desiccator and weighed.

The entire process should require one-half hour to complete when heat is properly regulated. The time will depend somewhat upon the kind of oil tested, as a very thin, rather low flash-point oil will not take as long as a heavy, thick, high flash-point oil.

EMULSIFYING PROPERTIES.—*Essential Features of Emulsifier.* The oil and water to be emulsified are contained in an ordinary commercial 100 c.c. graduated cylinder, 1 1/16 to 1 2/16 inches inside diameter. An oil or water bath is provided for maintaining the contents of the cylinder at a temperature of 130° F., except when a different temperature is specified, both during the stirring and subsequent settling out of the oil from the emulsion. The paddle used in stirring is a copper plate 4 3/4 inches long, between 3/4 and 7/8 inch wide, and 1/16 inch thick. Means are provided for revolving this paddle about a vertical axis parallel to and midway between its two longer edges, and for keeping the speed fairly constant at 1500 R. P. M. Some form of holder for the cylinders is a convenience but not a necessity, since on account of the ample clearance between paddle and cylinder, and the fact that a sample is stirred for only 5 minutes, a cylinder may be held by hand during the stirring. A stop should be provided, so that when the paddle is lowered into the cylinder (or bath raised), the distance from the bottom of the paddle to the bottom of the cylinder will be about 1/4 inch. To save time otherwise lost in waiting for the filled cylinders to come to the temperature

of the bath, it is desirable that the bath should be large enough to contain several cylinders.

Emulsion Test.—Forty c.c. of the emulsifying liquid is placed in a clean 100 c.c. graduated cylinder and 40 c.c. of the oil to be tested is added. The cylinder is then placed in the bath, and when the contents have reached the temperature required for the test, they are stirred by the paddle for 5 minutes. The paddle is stopped, withdrawn from the cylinder, and wiped clean. The cylinder is then allowed to stand for the specified time and is then inspected.

Demulsibility Test.—Pour 27 c.c. of the oil to be tested and 53 c.c. of distilled water into a cylinder; place cylinder in bath and heat to 130° F. Submerge the paddle and run it for 5 minutes at a speed of 1500 R. P. M. Stop the paddle, withdraw it from the cylinder and use the finger to wipe off the emulsion clinging to the paddle and to return it to the cylinder. Wipe off the paddle with paper so that it will not contaminate the next sample. Keep the temperature of the cylinder constant at 130° F. and take readings every minute of the position of the line of demarcation between the topmost layer of oil and the adjoining emulsion. The first reading is taken one minute after stopping the paddle. With oils which act normally, the rate of settling out of the oil increases up to a maximum and then decreases, and the maximum value, in c.c. per hour, is called the "demulsibility" and is recorded as the numerical result of the test. Each rate of settling is the average rate calculated from the time of stopping the paddle to the time of reading, as shown in the following condensed table:

Time	Time since stopping paddle	Reading at interface between oil and emulsion	C.c. of oil settled out	Rate of settling c.c. per hour
9.50	0	80	0	0
9.55	5	77	3	36
10.02	12	67	13	65
10.05	15	63	17	68
10.10	20	61	19	57

The demulsibility in this case would be 68, the highest value in the last column. In cases where the maximum rate of settling has not been reached at the end of one hour, the test is discontinued and the demulsibility taken as the number of c.c. which settled out in the hour.

PROTECTION.—A clean polished steel plate 2 inches long, 1/2 inch wide, and 1/8 inch thick, is coated by immersing in the lubricant which has been heated to a temperature of 212° F. The plate is removed while still hot, allowed to cool in a vertical position, and suspended vertically within a 10 per cent. salt solution.

SPECIFICATIONS

SPECIFICATIONS, LUBRICATING OILS (CLASS A OILS).—

General

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for the general lubrication of engines and machinery where a highly refined oil is not required. This oil is not to be used for steam-cylinder lubrication.

2. Only refined petroleum oils without the admixture of fatty oils resins, soap, or other compounds not derived from crude petroleum, will be considered.

3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Properties and Tests

4. *Flash- and Fire-points.*—The flash- and fire-points of the five grades shall not be lower than the following:

	Flash Deg. F.	Fire Deg. F.
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

5. *Viscosity.*—The viscosity of the five grades of oil at 100° Fahr. must be within the following limits:

	Seconds
Extra light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra heavy	470–520

6. *Color:* The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

7. *Pour Test:* The pour test shall not be above the following temperatures:

	Degrees F.
Extra light	35
Light	35
Medium	40
Heavy	45
Extra heavy	50

8. *Acidity:* Not more than 0.10 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

9. *Corrosion:* A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

10. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

SPECIFICATIONS FOR LUBRICATING OILS. (CLASS B.)—

General

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for the lubrication of turbines, dynamos, high-speed engines and other classes of machinery where an oil better than Class A is required. The oil must be satisfactory for use in circulating and forced-feed systems.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps, or other compounds not derived from crude petroleum will be considered.

3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Properties and Tests

4. *Flash- and Fire-points:* The flash- and fire-points of the five grades shall not be lower than the following:

	Flash Deg. F.	Fire Deg. F.
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

5. *Viscosity:* The viscosity of the five grades at 100° F. must be within the following limits:

	Seconds
Extra light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra heavy	470–520

6. *Color:* The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

7. *Pour Test:* The pour test shall not be above the following temperatures:

	Degrees F.
Extra light	35
Light	35
Medium	40
Heavy	45
Extra heavy	50

8. *Acidity:* Not more than 0.07 milligram of potassium hydroxide shall be required to neutralize 1 gram of oil.

9. *Corrosion:* A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

10. *Emulsifying Properties:* The oil shall separate completely in 30 minutes from an emulsion with:

1. Distilled water.
2. One per cent. salt solution.
3. Normal caustic soda solution.

The demulsibility shall not be less than 300.

11. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

SPECIFICATIONS FOR LUBRICATING OILS (CLASS C).—

General

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for lubrication of air compressors and internal-combustion engines, except aircraft, motor cycle and Diesel engines; also for the lubrication of turbines and other machinery where an oil better than Class B is required. This oil must be satisfactory for use in circulating and forced-feed systems.

2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps, or other compounds not derived from crude petroleum, will be considered.

3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Properties and Tests

4. *Flash- and Fire-points:* The flash- and fire-points of the five grades shall not be lower than the following:

	Flash Deg. F.	Fire Deg. F.
Extra light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra heavy	355	400

Oil for use in air compressors where the air leaving any stage or cylinder has a temperature above 212° F. shall have a flash-point not lower than 400° F.

5. *Viscosity:* The viscosity of the five grades at 100° F. must be within the following limits:

	Seconds
Extra light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra heavy	470–520

6. *Color:* The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

7. *Pour Test:* The pour test shall not be above the following temperatures:

	Degrees F.
Extra light	35
Light	35
Medium	40
Heavy	45
Extra heavy	50

8. *Acidity:* Not more than 0.05 milligram of potassium hydroxide shall be required to neutralize one gram of the oil.

9. *Corrosion:* A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

10. *Emulsifying Properties:* The oil shall separate completely in 30 minutes from an emulsion with:

1. Distilled water.
2. One per cent. salt solution.
3. Normal caustic soda solution.

The demulsibility shall not be less than 300.

11. *Carbon Residue:* The carbon residue shall not exceed the following:

	Per cent.
Extra light	0.10
Light	0.20
Medium	0.30
Heavy	0.40
Extra heavy	0.60

12. Further tests on oils of Class C may be required at the option of the department of the Government using the oils.

13. All tests shall be made according to the methods adopted by .he Committee on Standardization of Petroleum Specifications.

AIRCRAFT MACHINE-GUN OIL.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of machine guns on aircraft, for the c.c. interrupter gears and for gun oil for cleaning and oiling machine guns and small arms.

2. The oil must be a highly refined, filtered, straight-run petroleum oil, suitable in every way for the uses specified in Paragraph 1. It must be a pure petroleum product, without the addition of vegetable or animal oils or fats of any kind. It shall not contain any material which might gum or corrode metals under any conditions.

Properties and Tests

3. *Flash-point:* The flash-point shall not be less than 200° F.

4. *Viscosity:* The viscosity at 100° F. shall be within the following limits: 70 to 95 seconds.

5. *Pour Test:* The pour test shall be 45° or more below zero Fahr.

6. *Acidity:* Not more than 0.03 milligram of potassium hydroxide shall be required to neutralize 1 gram of oil.

7. *Carbon Residue:* The carbon residue must not be more than 0.03 per cent.

8. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

GUNS AND SMALL ARMS, OIL FOR.—(Report of Committee on Standardization of Petroleum Specifications.)

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for cleaning and oiling guns and small arms where aircraft machine-gun oil is not required; also for lubrication of the cylinders of ice machines, for lubrication of pneumatic tools and for hydraulic systems.

2. The oil must be a straight-run, highly refined petroleum oil, free from vegetable or animal oils or products derived from them; must be suitable in every way for the uses listed in Paragraph 1; and must not gum or corrode metals under any conditions.

3. These oils shall be supplied in two grades known as No. 100 and No. 125.

Properties and Tests

4. *Flash-point:* The flash-point must not be less than 300° F.

5. *Viscosity:* The viscosity at 100° Fahr. must be within the following limits:

No. 100 oil	95 to 110 seconds.
No. 125 oil	120 to 135 seconds.

6. *Pour Test:* The pour test must not be higher than 5° above zero F.

7. *Acidity:* Not more than 0.03 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

8. *Emulsifying Properties:* The oil shall separate completely in 30 minutes from an emulsion with:

1. Distilled water.
2. One per cent. salt solution.
3. Normal caustic soda solution.

The demulsibility shall not be less than 300.

9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

HOWITZERS, BRITISH TYPES, BUFFER OIL, RECOIL AND RECUPERATOR CYLINDERS.—(Report of Committee on Standardization of Petroleum Specifications, April, 1920.)

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for filling the recoil and recuperator cylinders of all British type howitzers and gun carriages.

2. The oil is to be a pure refined petroleum oil.

Properties and Tests

3. *The flash-point* shall not be lower than 265° F.

4. *Viscosity:* The viscosity at 100° F. shall be within the following limits:

65 to 75 seconds.

5. *Pour Test:* The pour test shall not be above 0° F.

6. *Acidity:* Not more than 0.05 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

7. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

CUP GREASE.—

General

1. This specification covers the grades of cup grease used by the United States Government and its agencies for the lubrication of such parts of motor equipment and other machinery as are lubricated by means of compression cups. No. 1/2 and No. 1 to be used in spindle cups or transmissions.

2. The grease must be a well-manufactured product, composed of a calcium soap and a highly refined mineral oil.

Properties and Tests

3. The mineral oil used in reducing the soaps must be a straight, well-refined mineral oil, with a viscosity at 100° F. of not less than 100 seconds.

4. *Soap Base:* This base to be a whole fat, such as pure tallow oil, neatsfoot oil, lard oil, horse oil or other pure animal oils used singly or in combination.

(*a*) No. 1/2 cup grease shall contain approximately 13 per cent. of a calcium soap made from an approved fat.

(*b*) No. 1 cup grease shall contain approximately 14 per cent. of a calcium soap made from an approved fat.

(*c*) No. 3 cup grease shall contain approximately 18 per cent. of a calcium soap made from an approved fat.

(*d*) No. 5 cup grease shall contain approximately 24 per cent. of a calcium soap made from an approved fat.

5. *Consistency:* These greases must be similar in consistency to the approved trade standards for No. 1/2, No. 1, No. 3, and No. 5 grease.

6. *Moisture:* The grease must be a boiled grease, containing not less than 1 per cent. or more than 3 per cent. of water when finished.

7. *Corrosion:* A clean copper plate must not be discolored when submerged in the grease for 24 hours at room temperature.

8. *Ash:* No. 1/2 grease. The ash shall not be greater than 1.7 per cent.
No. 1 grease. The ash shall not be greater than 1.8 per cent.
No. 3 grease. The ash shall not be greater than 2.3 per cent.
No. 5 grease. The ash shall not be greater than 3.5 per cent.

9. *Fillers:* The grease shall contain no fillers such as resin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler.

10. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

TRANSMISSION LUBRICANT.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of trans-

mission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

2. The lubricant must be a refined petroleum product, without the addition of any vegetable or animal oils or products derived from them, and be entirely free from fillers.

Properties and Tests

3. *Flash-point:* The flash-point shall not be lower than 460° F.

4. *Viscosity:* The viscosity at 210° F. must be within the following limits:

175 to 220 seconds.

5. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

MINERAL STEAM CYLINDER OIL FOR NON-CONDENSING ENGINES.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for non-condensing steam engine cylinder lubrication where a mineral oil is required; also as a stock oil for compounding.

Properties and Tests

2. The oil must be a well-refined petroleum oil without compounding of any nature.

3. *Flash-point:* The flash-point must not be less than 475° F.

4. *Viscosity:* The viscosity at 210° F. must be within the following limits:

135 to 165 seconds.

5. *Cold Test:* The cold test must not be above 45° F.

Precipitation Test: When 5 c.c. of the oil is mixed with 95 c.c. of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 c.c. (5 per cent. by volume of the original oil).

7. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

COMPOUND STEAM CYLINDER OIL FOR NON-CONDENSING ENGINES.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of steam cylinders of non-condensing engines and pumps where a compounded oil is required.

Properties and Tests

2. The oil must be a well-refined petroleum oil, compounded with not less than 5 per cent. nor more than 7 per cent. of acidless tallow oil or lard oil.

3. *Flash-point:* The flash-point must not be less than 475° F.

4. *Viscosity:* The viscosity at 210° F. must be within the following limits:

120 to 150 seconds.

5. *Cold Test:* The cold test must not be above 45° F.

6. *Precipitation Test:* When 5 c.c. of the oil is mixed with 95 c.c. of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 c.c. (5 per cent. by volume of the original oil).

7. *Acidity:* The oil must not contain more than 0.40 per cent. of acid calculated as oleic acid (equivalent to 0.80 mg. *KOH* per gram of oil).

8. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

FLOOR OIL.—

General

1. This specification covers the grade of oil used by the United States Government and its agencies for polishing and preserving wooden floors.

2. The oil must be a well-refined straight petroleum oil.

Properties and Tests

3. *Flash-point:* The flash-point shall not be less than 300° F.

4. *Viscosity:* The viscosity at 100° F. shall be within the following limits:

60 to 100 seconds.

5. *Pour Test:* The pour test shall not be greater than 35° F.

6. *Color:* The oil shall be pale or red in color. Black oil will not be accepted.

7. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

GEAR-CHAIN AND WIRE-ROPE LUBRICANT.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication and protection of chains, wire ropes and gears of cranes, dredges, steam shovels and all other heavy equipment, for the lubrication and protection of the gears and ropes of balloon hoists; and for swabbing the wires and cables of aircraft.

2. The oil must be a petroleum product only, free from vegetable or animal oils or products derived from them. It must be entirely free from fillers, such as talc, resin, and all materials of every nature not related to the original product.

Properties and Tests

3. *Viscosity:* The viscosity at 210° F. must be within the following limits:

900 to 1100 seconds.

4. *Protection:* When applied to a plate of polished steel the lubricant must protect the steel for a period of 30 days when immersed in a 10 per cent. salt solution.

5. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

LIBERTY AERO AND MOTORCYCLE OIL.—

General

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of stationary-cylinder aircraft engines and motorcycle engines.

2. The oil must be made from pure, highly refined petroleum products and must be suitable in every way for the entire lubrication of stationary-cylinder aircraft engines and motorcycle engines operating under all conditions. The oil must not contain moisture, sulphonates, soap, resin, or any tarry constituents which would indicate adulteration or lack of proper refining.

Properties and Tests

3. *Flash-point:* The flash-point shall not be lower than 400° F.

4. *Viscosity:* The viscosity of the oil at 210° F. shall be within the following limits:

80 to 90 seconds.

5. *Pour Test:* The pour test for summer oil shall not be above 45° F. For winter oil not above 20° F.

6. *Acidity:* Not more than 0.10 milligram of potassium hydroxide shall be required to neutralize 1 gram of the oil.

7. *Emulsifying Properties:* The oil shall separate completely in 1 hour from an emulsion with:

1. Distilled water.
2. One per cent. salt solution.

At a temperature of 180° F.

8. *Carbon Residue:* The carbon residue shall not be over 1.5 per cent.

9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

SECTION 11d

U. S. GOVERNMENT SPECIFICATIONS, MOTOR GASOLINE TEST METHODS

REPORT OF COMMITTEE ON STANDARDIZATION OF PETROLEUM SPECIFICATIONS, MOTOR GASOLINE.—(November 25, 1919):

Revised Specifications for Motor Gasoline

Quality: Gasoline to be high grade, refined, and free from water and all impurities, and shall have a vapor tension not greater than 10 pounds per square inch at 100° F. temperature, same to be determined in accordance with the current "Rules and Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight," as issued by the Interstate Commerce Commission.

Inspection: Before acceptance the gasoline will be inspected. Samples of each lot will be taken at random. These samples immediately after drawing will be retained in a clean, absolutely tight closed vessel and a sample for test taken from the mixture in this vessel directly into the test vessel.

Specifications

(*a*) Boiling point must not be higher than 60° C. (140° F.).
(*b*) Twenty per cent. of the sample must distill below 105° C. (221° F.).
(*c*) Fifty per cent. must distill below 140° C. (284° F.).
(*d*) Ninety per cent. must distill below 190° C. (374° F.).
(*e*) The end or dry-point of distillation must not be higher than 225° C. (437° F.).
(*f*) Not less than 95 per cent. of the liquid will be recovered in the receiver from the distillation.

Test

One hundred cubic centimetres will be taken as a test sample. The apparatus and method of conducting the distillation test shall be that adopted by Sub-Committee XI of Committee D-1 of the American Society for Testing Materials,* with the following modifications:

First, the temperature shall be read against fixed percentage points; and, second, the thermometer shall be as hereinafter described.

Flask

The flask used shall be the standard 100 c.c. Engler Flask, described in the various text-books on petroleum. Dimensions are as follows:

* American Society for Testing Materials, Year Book for 1915, pp. 568–569; or pt. 1, Committee Reports, 1916, Vol. 16, pp. 518–521. See also Bureau of Mines Technical Papers Nos. 166 and 214.

Dimensions of Flask

Dimensions	Cm.	Inches
Outside diameter of bulb	6.5	2.56
Inside diameter of neck	1.6	0.63
Length of neck	15.0	5.91
Length of vapor tube	10.0	3.94
Outside diameter of vapor tube	0.6	0.24

Position of vapor tube, 9 cm. (3.55 inches) above the surface of the gasoline when the flask contains its charge of 100 c.c. The tube is approximately in the middle of the neck. The observance of the prescribed dimensions is considered essential to the attainment of uniformity of results.

The flask shall be supported on a ring of asbestos having a circular opening 1 1/4 inches in diameter; this means that only this limited portion of the flask is to be heated. The use of wire gauze is forbidden.

Condenser

The condenser shall consist of a thin-walled tube of metal (brass or copper) 1/2-inch internal diameter and 22 inches long. It shall be set at an angle of 75° from the perpendicular and shall be surrounded with a cooling jacket of the trough type. The lower end of the condenser shall be cut off at an acute angle and shall be curved down for a length of 3 inches. The condenser jacket shall be 15 inches long.

Thermometer

The thermometer shall be made of selected enamel-backed tubing having a diameter between 5.5 and 7 mm. The bulb shall be of Jena normal or Corning normal glass, its diameter shall be less than that of the stem and its length between 10 and 15 mm. The total length of the thermometer shall be approximately 380 mm. The range shall cover 0° C. (32° F.) to 270° C. (518° F.), with the length of the graduated portion between the limits of 210 to 250 mm. The point marking a temperature of 35° C. (95° F.) shall not be less than 100 mm. nor more than 120 mm. from the top of the bulb. For commercial use the thermometer may be graduated in the Fahrenheit scale.

The scale shall be graduated for total immersion. The accuracy must be within about 0.5° C. The space above the meniscus must be filled with an inert gas, such as nitrogen, and the stem and bulb must be thoroughly aged and annealed before being graduated.

Source of Heat in Gasoline Distillation

The source of heat in distilling gasoline may be a gas burner, an alcohol lamp, or an electric heater.

Procedure and Details of Manipulation in Conducting Distillations

1. If an electric heater is used it is started first to warm it.
2. The condenser box is filled with water containing a liberal portion of cracked ice.

3. The charge of gasoline is measured into the clean, dry Engler flask from a 100 c.c. graduate. The graduate is used as a receiver for distillates without any drying. This procedure eliminates errors due to incorrect scaling of graduates and also avoids the creation of an apparent distillation loss due to the impossibility of draining the gasoline entirely from the graduate.

4. The above-mentioned graduate is placed under the lower end of the condenser tube so that the latter extends downward below the top of the graduate at least 1 inch. The condenser tube should be so shaped and bent that the tip can touch the wall of the graduate on the side adjacent to the condenser box. This detail permits distillates to run down the side of the graduate and avoids disturbance of the meniscus caused by the falling of drops. The graduate is moved occasionally to permit the operator to ascertain that the speed of distillation is right, as indicated by the rate at which drops fall. The proper rate is from 4 c.c. to 5 c.c. per minute, which is approximately 2 drops a second. The top of the graduate is covered, preferably by several thicknesses of filter paper, the condenser tube passing through a snugly fitting opening. This minimizes evaporation losses due to circulation of air through the graduate, and also excludes any water that may drip down the outside of the condenser tube on account of condensation on the ice-cooled condenser box.

5. A boiling stone (a bit of unglazed porcelain or other porous material) is dropped into the gasoline in the Engler flask. The thermometer is equipped with a well-fitted cork and its bulb covered with a thin film of absorbent cotton (preferably the long-fibred variety sold for surgical dressing). The quantity of cotton used shall be not less than 0.005 nor more than 0.010 g. (5 to 10 milligrams). The thermometer is fitted into the flask with the bulb just below the lower level of the side neck opening. The flask is connected with the condenser tube.

6. Heat must be so applied that the first drop of the gasoline falls from the end of the condenser tube in not less than 5 or more than 10 minutes. The initial boiling point is the temperature shown by the thermometer when the first drop falls from the end of the condenser tube into the graduate. The operator should not allow himself to be deceived as sometimes (if the condenser tube is not dried from a previous run) a drop will be obtained, and it will be some time before a second one falls; in this case the first drop should be ignored. The amount of heat is then increased so that the distillation proceeds at a rate of from 4 c.c. to 5 c.c. per minute. The thermometer is read as each of the selected percentage marks is reached. The maximum boiling point, or dry-point, is determined by continuing the heating after the flask bottom has boiled dry until the column of mercury reaches a maximum and then starts to recede consistently.

7. Distillation loss is determined as follows: The condenser tube is allowed to drain for at least five minutes after heat is shut off, and a final reading taken of the quantity of distillate collected in the receiving graduate. The distillation flask is removed from the condenser and thoroughly cooled as soon as it can be handled. The condensed residue is poured into a small graduate or graduated test tube and its volume measured. The sum of its volume and the volume collected in the receiving graduate, subtracted from 100 c.c., gives the figure for distillation loss.

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